NOVEL PHOSPHORUS-CONTAINING THYROMIMETICS

FIELD OF THE INVENTION

The present invention is directed toward phosphonic acid-containing compounds that are thyroid receptor ligands, pharmaceutically acceptable salts, and to prodrugs of these compounds as well as their preparation and uses for preventing and/or treating metabolic diseases such as obesity, NASH, hypercholesterolemia and hyperlipidemia as well as associated conditions such as atherosclerosis, coronary heart disease, impaired glucose tolerance and diabetes. The invention is also related to the liver specific delivery of thyroid receptor ligands and the use of these compounds for the prevention and treatment of diseases responsive to modulation of T3-responsive genes in the liver.

BACKGROUND

The following description of the background is provided to aid in understanding, but is not admitted to be, or to describe, prior art. All publications and their cited references are incorporated by reference in their entirety.

Thyroid hormones (TH) are synthesized in the thyroid in response to thyroid stimulating hormone (TSH), which is secreted by the pituitary gland in response to various stimulants (*e.g.*, thyrotropin-releasing factor (TRF) from the hypothalamus). Thyroid hormones are iodinated *O*-aryl tyrosine analogues excreted into the circulation primarily as T4. T4 is rapidly deiodinated in the liver and kidney by thyroxine 5'-deiodinase to T3, which is the most potent TH. T3 is metabolized to inactive metabolites via a variety of pathways, including pathways involving deiodination, glucuronidation, sulfation, deamination, and decarboxylation. Most of the metabolic pathways reside in the liver.

THs have profound physiological effects in animals and humans. Hyperthyroidism is associated with increased body temperature, general nervousness, weight loss despite increased appetite, muscle weakness and fatigue, increased bone resorption and enhanced calcification, and a variety of cardiovascular changes, including increased heart rate, increased stroke volume, increased cardiac index, cardiac hypertrophy, decreased peripheral vascular resistance, and increased pulse pressure. Hypothyroidism is generally associated with the opposite effects.

The biological activity of THs is mediated largely through thyroid hormone receptors (TRs). TRs belong to the receptor superfamily known as nuclear receptors, which, along with its common partner, the retinoid X receptor, form heterodimers that act as ligand-inducible transcription factors. Like other nuclear receptors, TRs have a ligand binding domain and a DNA binding domain and regulate gene expression through ligand-dependent interactions with DNA response elements (thyroid response elements, TREs). Currently, the literature shows that TRs are encoded by two distinct genes (TRα and TRβ), which produce several isoforms through alternative splicing (Williams, *Mol Cell Biol.* 20(22):8329-42 (2000); Nagaya, *et al., Biochem Biophys Res Commun* 226(2):426-30 (1996)). The major isoforms that have so far been identified are TRα-1, TRα-2, TRβ-1 and TRβ-2. TRα-1 is ubiquitously expressed in the rat with highest expression in skeletal muscle and brown fat. TRβ-1 is also ubiquitously expressed with highest expression in the liver, brain and kidney. TRβ-2 is expressed in the anterior pituitary gland and specific regions of the hypothalamus as well as the developing brain and inner ear. In the rat and mouse liver, TRβ-1 is the predominant isoform (80%). The TR isoforms found in human and rat are highly homologous with respect to their amino acid sequences which suggest that each serves a specialized function.

TSH is an anterior pituitary hormone that regulates thyroid hormone production. TSH formation and secretion is in turn regulated by the hypothalamic thyrotropin releasing factor (TRF). TSH controls the uptake of iodide by the thyroid, the subsequent release of iodinated thyronines from thyroglobulin (*e.g.*, T3, T4) as well as possibly the intrapituitary conversion of circulating T4 to T3. Compounds that mimic T3 and T4 can negatively regulate both TSH and TRF secretion resulting in suppression of TSH levels and decreased levels of T3 and other iodinated thyronines. Negative regulation of TSH is postulated based on co-transfection and knockout studies (Abel *et al.*, J. Clin. Invest., 104, 291-300, (1999)) to arise through activation of the thyroid receptor TRβ, possibly the isoform TRβ-2, which is highly expressed in the pituitary.

The most widely recognized effects of THs are an increase in metabolic rate, oxygen consumption and heat production. T3 treatment increases oxygen consumption in isolated perfused liver and isolated hepatocytes. (Oh, *et al., J. Nutr.* 125(1):112-24 (1995); Oh, *et al., Proc. Soc. Exp. Biol. Med.* 207(3): 260-7 (1994)) Liver mitochondria from hyperthyroid rats exhibit increased oxygen consumption (Carreras, *et al., Am J Physiol Heart Circ Physiol.* 281(6):H2282-8 (2001) and higher activities of enzymes in

the oxidative pathways (Dummler *et al., Biochem J.* 317(3):913-8 (1996), Schmehl, *et al., FEBS Lett.* 375(3):206-10 (1995), Harper *et al., Can J Physiol Pharmacol.* 72(8):899-908 (1994)). Conversely, mitochondria from hypothyroid rats show decreased oxygen consumption. Increased metabolic rates are associated with increased mitochondrialgenesis and the associated 2- to 8-fold increase in mitochondrial mRNA levels. Some of the energy produced from the increased metabolic rate is captured as ATP (adenosine 5'-triphosphate), which is stored or used to drive biosynthetic pathways (*e.g.,* gluconeogenesis, lipogenesis, lipoprotein synthesis). Much of the energy, however, is lost in the form of heat (thermogenesis), which is associated with an increase in mitochondrial proton leak possibly arising from TH-mediated effects on mitochondrial membrane, uncoupling proteins, enzymes involved in the inefficient *sn*-glycerol 3-phosphate shuttle such as mitochondrial *sn*-glycerol 3-phosphate dehydrogenase (mGPDH), and/or enzymes associated with proton leakage such as the adenine nucleotide transporter (ANT), Na^+/K^+-ATPase, Ca^{2+}-ATPase and ATP synthase.

THs also stimulate metabolism of cholesterol to bile acids. Hyperthyroidism leads to decreased plasma cholesterol levels, which is likely due to increased hepatic LDL receptor expression. Hypothyroidism is a well-established cause of hypercholesterolemia and elevated serum LDL. L-T3 is known to lower plasma cholesterol levels. The effects of T3 are attributed to TRβ since TRβ-deficient mice are resistant to T3-induced reduction in cholesterol levels. The effects on cholesterol levels have been postulated to result from direct effects on LDL receptor expression, enzymes involved in conversion of cholesterol to bile acids such as the rate-limiting enzyme cholesterol 7α-hydroxylase (CYP7A) and/or possibly enzymes involved in cholesterol synthesis such as HMG CoA reductase. In addition, THs are known to affect levels of other lipoproteins linked to atherosclerosis. THs stimulate apo AI and the secretion of apo AI in HDL while reducing apo AII. Accordingly, one would expect T3 and T3 mimetics to inhibit the atherosclerotic process in the cholesterol fed animal.

THs simultaneously increase de novo fatty acid synthesis and oxidation through effects on enzymes such as ACC, FAS, and spot-14. THs increase circulating free fatty acids (FFA) levels in part by increasing production of FFAs from adipose tissue via TH-induced lipolysis. In addition, THS increase mitochondrial enzyme levels involved in FFA oxidation, *e.g.,* carnitine palmitoyltransferase 1 (CPT-1) and enzymes involved in energy storage and consumption.

The liver represents a major target organ of THs. Microarray analysis of hepatic gene expression from livers of hypothyroid mice and mice treated with T3 showed changes in mRNA levels for 55 genes (14 positively regulated and 41 negatively regulated) (Feng, *et al., Mol. Endocrinol.* 14(7): 947-55 (2000). Others have estimated that approximately 8% of the hepatic genes are regulated by T3. Many of these genes are important to both fatty acid and cholesterol synthesis and metabolism. T3 is also known to have other effects in liver, including effects on carbohydrates through increased glycogenolysis and gluconeogenesis and decreased insulin action.

The heart is also a major target organ of THs. THs lower systemic vascular resistance, increase blood volume and produce inotropic and chronotropic effects. Overall TH results in increased cardiac output, which may suggest that T3 or T3 mimetics might be of use to treat patients with compromised cardiac function (*e.g.,* patients undergoing coronary artery bypass grafting (CABG) or cardiac arrest) (U.S. 5,158,978). The changes in cardiac function are a result of changes in cardiac gene expression. Increased protein synthesis and increased cardiac organ weight are readily observed in T3-treated animals and represent the side effect of T3 that limits therapeutic use. TRβ knockout mice exhibit high TSH and T4 levels and increased heart rate suggesting that they retain cardiac sensitivity and therefore that the cardiac effects are via TRα. TRα knockouts exhibit reduced heart rates.

THs also play a role in the development and function of brown and white adipose tissue. Both TRα and TRβ are expressed in brown adipose tissue (BAT). THs induce differentiation of white adipose tissue (WAT) as well as a variety of lipogenic genes, including ACC, FAS, glucose-6-phosphate dehydrogenase and spot-14. Overall THs play an important role in regulating basal oxygen consumption, fat stores, lipogenesis and lipolysis (Oppenheimer, *et al., J. Clin. Invest.* 87(1): 125-32 (1991)).

TH has been used as an antiobesity drug for over 50 years. In the 1940s TH was used alone, whereas in the 1950s it was used in combination with diuretics and in the 1960s in combination with amphetamines. Hyperthyroidism is associated with increased food intake but is also associated with an overall increase in the basal metabolic rate (BMR). Hyperthyroidism is also associated with decreased body weight (ca. 15%) whereas hypothyroidism is associated with a 25-30% increase in body weight. Treating hypothyroidism patients with T3 leads to a decrease in body weight for most patients but not all (17% of the patients maintain weight).

The effectiveness of TH treatment is complicated by the need for supraphysiological doses of T3 and the associated side effects, which include cardiac problems, muscle weakness and excess erosion of body mass. Long-term therapy has also been associated with bone loss. With these side effects, the medical community has tended to use thyroxine at low doses as an adjunct to dietary treatments. At these doses, TH has little effect on body weight or BMR.

The effectiveness of T3 to induce weight loss may be attenuated by defects in TH action. In comparison to normal animals, higher T3 doses were required in *ob/ob* mice to affect oxygen consumption, which was only observed in muscle, with no changes in liver and BAT. (Oh, *et al., J. Nutr.* 125(1): 112-24 (1995); Oh, *et al., Proc. Soc. Exp. Biol. Med.* 207(3): 260-7 (1994)). These effects were at least partially attributed to decreased uptake of T3 by the liver.

T3 analogues have been reported. Many were designed for use as cholesterol-lowering agents. Analogues that lower cholesterol and various lipoproteins (*e.g.*, LDL cholesterol and Lp(a)) without generating adverse cardiac effects have been reported (*e.g.*, Underwood, *et al., Nature* 324: 425-9 (1986)). In some cases the improved therapeutic profile is attributed to increased specificity for the TR-β wherein other cases it may be due to enhanced liver distribution. (Stanton, *et al., Bioorg. Med. Chem. Lett.* 10(15): 1661-3 (2000); Dow *et al., Bioorg. Med. Chem. Lett.*, 13(3): 379-82 (2003)).

T3 and T3 mimetics are thought to inhibit atherosclerosis by modulating the levels of certain lipoproteins known to be independent risk factors or potential risk factors of atherosclerosis, including low density lipoprotein (LDL)-cholesterol, high density lipoprotein (HDL)-cholesterol, apoAI, which is a major apoprotein constituent of high density lipoprotein (HDL) particles and lipoprotein (a) or Lp (a).

Lp(a) is an important risk factor, elevated in many patients with premature atherosclerosis. Lp(a) is considered highly atherogenic (de Bruin *et al., J. Clin. Endo. Metab.*, 76, 121-126 (1993)). In man, Lp(a) is a hepatic acute phase protein that promotes the binding of LDL to cell surfaces independent of LDL receptors. Accordingly, Lp(a) is thought to provide supplementary cholesterol to certain cells, *e.g.*, cells involved in inflammation or repair. Lp(a) is an independent risk factor for premature atherosclerosis. Lp(a) is synthesized in the liver.

Apolipoprotein AI or apoAI is the major component of HDL, which is an independent risk factor of atherosclerosis. apoAI is thought to promote the efflux of cholesterol from peripheral tissues and higher levels of HDL (or apoAI) result in decreased risk of atherosclerosis.

Hyperthyroidism worsens glycemic control in type 2 diabetics. TH therapy is reported to stimulate hepatic gluconeogenesis. Enzymes specific to gluconeogenesis and important for controlling the pathway and its physiological role of producing glucose are known to be influenced by TH therapy. Phosphoenolpyruvate carboxykinase (PEPCK) is upregulated by TH (Park *et al, J.Biol. Chem.*, 274, 211 (1999)) whereas others have found that glucose 6-phosphatase is upregulated (Feng *et al., Mol. Endrocrinol.*, 14, 947 (2000)). TH therapy is also associated with reduced glycogen levels.

TH therapy results in improved non insulin stimulated and insulin stimulated glucose utilization and decreased insulin resistance in the muscle of ob/ob mice. (Oh *et al., J. Nutr.* , 125, 125 (1995)).

There is still a need for novel thyromimetics that can be used to modulate cholesterol levels, to treat obesity, and other metabolic disorders especially with reduced undesirable effects.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1a. Depicts the binding of T3 to the TRα1 receptor using a homologous displacement reaction.

Figure 1b. Depicts the binding of T3 to the Rβ1 receptor using a homologous displacement reaction.

Figure 1c. Depicts the binding of Compound 17 to the TRα1 receptor using a heterologous displacement reaction.

Figure 1d. Depicts the binding of Compound 17 to the TRβ1 receptor using a heterologous displacement reaction.

Figure 1e. Depicts the binding of Compound 7 to the TRα1 receptor using a heterologous displacement reaction.

Figure 1f. Depicts the binding of Compound 7 to the TRβ1 receptor using a heterologous displacement reaction.

Figure 2a. Depicts the dose response of serum cholesterol levels to Compound 17 in cholesterol fed rats.

Figure 2b. Depicts the dose response of serum cholesterol levels to Compound 7 in cholesterol fed rats.

Figure 3a. Depicts the effect of Compound 17 on the weight of the heart in cholesterol fed rats.

Figure 3b. Depicts the effect of Compound 7 on the weight of the heart in cholesterol fed rats.

Figure 4a. Depicts the effect of Compound 17 on cardiac GPDH activity in cholesterol fed rats.

Figure 4b. Depicts the effect of Compound 7 on cardiac GPDH activity in cholesterol fed rats.

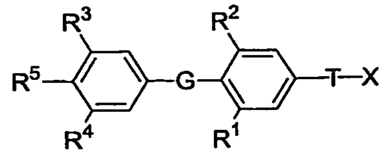
Figure 5. Depicts the dose response of serum cholesterol levels to Compound 13-1-*cis* in cholesterol-fed rats.

SUMMARY OF THE INVENTION

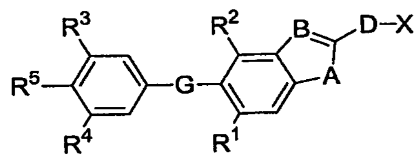
The present invention relates to phosphonic acid containing compounds that bind to thyroid receptors in the liver. Activation of these receptors results in modulation of gene expression of genes regulated by thyroid hormones. The present invention also relates to pharmaceutically acceptable salts and co-crystals, prodrugs, and pharmaceutically acceptable salts and co-crystals of these prodrugs of these compounds. The compounds can be used to treat diseases and disorders including metabolic diseases. In one aspect, the phosphonic acid-containing compounds are useful for improving efficacy, improving the therapeutic index, *e.g.*, decreasing non-liver related toxicities and side effects, or for improving liver selectivity, *i.e.*, increasing distribution of an active drug to the liver relative to extrahepatic tissues and more specifically increasing distribution of the an active drug to the nucleus of liver cells relative to the nucleus of extrahepatic tissue cells (including heart, kidney and pituitary). Prodrugs of the phosphonic acid-containing compounds are useful for increasing oral bioavailability and sustained delivery of the phosphosphonic acid-containing compounds.

In another aspect, the present invention relates to compounds of Formula I, II, III, and VIII The compounds of Formula I, II, III, and VIII may be an active form or a prodrug thereof. Further included are pharmaceutically acceptable salts, including but not limited to acid addition salts and physiological salts, and co-crystals of said compounds of Formula I, II, III, and VIII . Further included in the present invention are prodrugs of compounds of Formula I, II, III, and VIII that are active forms, and

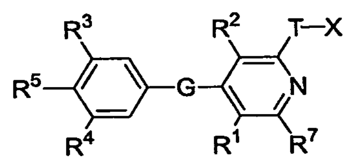
pharmaceutically acceptable salts, including but not limited to acid addition salts and physiological salts, and co-crystals thereof. Further included are methods of making and using the compounds of the present invention.



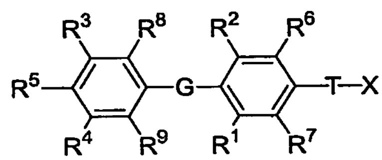
Formula I



Formula II



Formula III



Formula VIII

Some of the compounds of Formula I, II, III, and VIII have asymmetric centers, thus included in the present invention are racemic mixtures, enantiomerically enriched mixtures, diastereomeric mixtures, including diastereomeric enriched mixtures, and

individual stereoisomers of the compounds of Formula I, II, III and VIII and prodrugs thereof.

DEFINITIONS

As used herein, the following terms are defined with the following meanings, unless explicitly stated otherwise.

T groups that have more than one atom are read from left to right wherein the left atom of the T group is connected to the phenyl group bearing the R^1 and R^2 groups, and the right atom of the T group is linked to the phosphorus atom in X. For example, when T is -O-CH_2- or –N(H)C(O)- it means ~phenyl-O-CH_2-P(O)YR^{11}Y'R^{11} and ~phenyl-N(H)C(O)-P(O)YR^{11}Y'R^{11}.

The term "alkyl" refers to a straight or branched or cyclic chain hydrocarbon radical with only single carbon-carbon bonds. Representative examples include methyl, ethyl, propyl, isopropyl, cyclopropyl, butyl, isobutyl, *tert*-butyl, cyclobutyl, pentyl, cyclopentyl, hexyl, and cyclohexyl, all of which may be optionally substituted. Alkyl groups are C_1-C_{12}.

The term "aryl" refers to aromatic groups which have 5-14 ring atoms and at least one ring having a conjugated pi electron system and includes carbocyclic aryl, heterocyclic aryl and biaryl groups, all of which may be optionally substituted.

Carbocyclic aryl groups are groups which have 6-14 ring atoms wherein the ring atoms on the aromatic ring are carbon atoms. Carbocyclic aryl groups include monocyclic carbocyclic aryl groups and polycyclic or fused compounds such as optionally substituted naphthyl groups.

Heterocyclic aryl or heteroaryl groups are groups which have 5-14 ring atoms wherein 1 to 4 heteroatoms are ring atoms in the aromatic ring and the remainder of the ring atoms being carbon atoms. Suitable heteroatoms include oxygen, sulfur, nitrogen, and selenium. Suitable heteroaryl groups include furanyl, thienyl, pyridyl, pyrrolyl, N-lower alkyl pyrrolyl, pyridyl-N-oxide, pyrimidyl, pyrazinyl, imidazolyl, and the like, all optionally substituted.

The term "biaryl" represents aryl groups which have 5-14 atoms containing more than one aromatic ring including both fused ring systems and aryl groups substituted with other aryl groups. Such groups may be optionally substituted. Suitable biaryl groups include naphthyl and biphenyl.

The term "optionally substituted" or "substituted" includes groups substituted by one to six substituents, independently selected from lower alkyl, lower aryl, lower aralkyl, lower cyclic alkyl, lower heterocycloalkyl, hydroxy, lower alkoxy, lower aryloxy, perhaloalkoxy, aralkoxy, lower heteroaryl, lower heteroaryloxy, lower heteroarylalkyl, lower heteroaralkoxy, azido, amino, halo, lower alkylthio, oxo, lower acylalkyl, lower carboxy esters, carboxyl, -carboxamido, nitro, lower acyloxy, lower aminoalkyl, lower alkylaminoaryl, lower alkylaryl, lower alkylaminoalkyl, lower alkoxyaryl, lower arylamino, lower aralkylamino, sulfonyl, lower -carboxamidoalkylaryl, lower -carboxamidoaryl,lower hydroxyalkyl, lower haloalkyl, lower alkylaminoalkylcarboxy-, lower aminocarboxamidoalkyl-, cyano, lower alkoxyalkyl, lower perhaloalkyl, and lower arylalkyloxyalkyl.

"Substituted aryl" and "substituted heteroaryl" refers to aryl and heteroaryl groups substituted with 1-3 substituents. These substituents are selected from the group consisting of lower alkyl, lower alkoxy, lower perhaloalkyl, halo, hydroxy, and amino.

The term "-aralkyl" refers to an alkylene group substituted with an aryl group. Suitable aralkyl groups include benzyl, picolyl, and the like, and may be optionally substituted. "Heteroarylalkyl" refers to an alkylene group substituted with a heteroaryl group.

The term "alkylaryl-" refers to an aryl group substituted with an alkyl group. "Lower alkylaryl-" refers to such groups where alkyl is lower alkyl.

The term "lower" referred to herein in connection with organic radicals or compounds respectively defines such as with up to and including 10, in one aspect up to and including 6, and in another aspect one to four carbon atoms. Such groups may be straight chain, branched, or cyclic.

The term "cyclic alkyl" or "cycloalkyl" refers to alkyl groups that are cyclic of 3 to 10 carbon atoms, and in one aspect are 3 to 6 carbon atoms Suitable cyclic groups include norbornyl and cyclopropyl. Such groups may be substituted.

The term "heterocyclic", "heterocyclic alkyl" or "heterocycloalkyl" refer to cyclic groups of 3 to 10 atoms, and in one aspect are 3 to 6 atoms, containing at least one heteroatom, in a further aspect are 1 to 3 heteroatoms. Suitable heteroatoms include oxygen, sulfur, and nitrogen. Heterocyclic groups may be attached through a nitrogen or through a carbon atom in the ring. The heterocyclic alkyl groups include unsaturated cyclic, fused cyclic and spirocyclic groups. Suitable heterocyclic groups include pyrrolidinyl, morpholino, morpholinoethyl, and pyridyl.

The terms "arylamino" (a), and "aralkylamino" (b), respectively, refer to the group -NRR' wherein respectively, (a) R is aryl and R' is hydrogen, alkyl, aralkyl, heterocycloalkyl, or aryl, and (b) R is aralkyl and R' is hydrogen, aralkyl, aryl, alkyl or heterocycloalkyl.

The term "acyl" refers to -C(O)R where R is alkyl, heterocycloalkyl, or aryl.

The term "carboxy esters" refers to -C(O)OR where R is alkyl, aryl, aralkyl, cyclic alkyl, or heterocycloalkyl, all optionally substituted.

The term "carboxyl" refers to -C(O)OH.

The term "oxo" refers to =O in an alkyl or heterocycloalkyl group.

The term "amino" refers to -NRR' where R and R' are independently selected from hydrogen, alkyl, aryl, aralkyl and heterocycloalkyl, all except H are optionally substituted; and R and R′ can form a cyclic ring system.

The term "-carboxylamido" refers to -CONR$_2$ where each R is independently hydrogen or alkyl.

The term "-sulphonylamido" or "-sulfonylamido" refers to –S(=O)$_2$NR$_2$ where each R is independently hydrogen or alkyl.

The term "halogen" or "halo" refers to -F, -Cl, -Br and -I.

The term "alkylaminoalkylcarboxy" refers to the group alkyl-NR-alk-C(O)-O- where "alk" is an alkylene group, and R is a H or lower alkyl.

The term "sulphonyl" or "sulfonyl" refers to –SO$_2$R, where R is H, alkyl, aryl, aralkyl, or heterocycloalkyl.

The term "sulphonate" or "sulfonate" refers to –SO$_2$OR, where R is -H, alkyl, aryl, aralkyl, or heterocycloalkyl.

The term "alkenyl" refers to unsaturated groups which have 2 to 12 atoms and contain at least one carbon-carbon double bond and includes straight-chain, branched-chain and cyclic groups. Alkenyl groups may be optionally substituted. Suitable alkenyl groups include allyl. "1-alkenyl" refers to alkenyl groups where the double bond is between the first and second carbon atom. If the 1-alkenyl group is attached to another group, *e.g.*, it is a W substituent attached to the cyclic phosphonate, it is attached at the first carbon.

The term "alkynyl" refers to unsaturated groups which have 2 to 12 atoms and contain at least one carbon-carbon triple bond and includes straight-chain, branched-chain and cyclic groups. Alkynyl groups may be optionally substituted. Suitable alkynyl groups include ethynyl. "1-alkynyl" refers to alkynyl groups where the

triple bond is between the first and second carbon atom. If the 1-alkynyl group is attached to another group, *e.g.*, it is a W substituent attached to the cyclic phosphonate, it is attached at the first carbon.

The term "alkylene" refers to a divalent straight chain, branched chain or cyclic saturated aliphatic group. In one aspect the alkylene group contains up to and including 10 atoms. In another aspect the alkylene chain contains up to and including 6 atoms. In a further aspect the alkylene groups contains up to and including 4 atoms. The alkylene group can be either straight, branched or cyclic.

The term "acyloxy" refers to the ester group -O-C(O)R, where R is H, alkyl, alkenyl, alkynyl, aryl, aralkyl, or heterocycloalkyl.

The term "aminoalkyl-" refers to the group NR_2-alk- wherein "alk" is an alkylene group and R is selected from -H, alkyl, aryl, aralkyl, and heterocycloalkyl.

The term "alkylaminoalkyl-" refers to the group alkyl-NR-alk- wherein each "alk" is an independently selected alkylene, and R is H or lower alkyl. "Lower alkylaminoalkyl-" refers to groups where the alkyl and the alkylene group is lower alkyl and alkylene, respectively.

The term "arylaminoalkyl-" refers to the group aryl-NR-alk- wherein "alk" is an alkylene group and R is -H, alkyl, aryl, aralkyl, or heterocycloalkyl. In "lower arylaminoalkyl-", the alkylene group is lower alkylene.

The term "alkylaminoaryl-" refers to the group alkyl-NR-aryl- wherein "aryl" is a divalent group and R is -H, alkyl, aralkyl, or heterocycloalkyl. In "lower alkylaminoaryl-", the alkyl group is lower alkyl.

The term "alkoxyaryl-" refers to an aryl group substituted with an alkyloxy group. In "lower alkyloxyaryl-", the alkyl group is lower alkyl.

The term "aryloxyalkyl-" refers to an alkyl group substituted with an aryloxy group.

The term "aralkyloxyalkyl-" refers to the group aryl-alk-O-alk- wherein "alk" is an alkylene group. "Lower aralkyloxyalkyl-" refers to such groups where the alkylene groups are lower alkylene.

The term "alkoxy-" or "alkyloxy-" refers to the group alkyl-O-.

The term "alkoxyalkyl-" or "alkyloxyalkyl-" refer to the group alkyl-O-alk- wherein "alk" is an alkylene group. In "lower alkoxyalkyl-", each alkyl and alkylene is lower alkyl and alkylene, respectively.

The terms "alkylthio-" and "alkylthio-" refer to the group alkyl-S-.

The term "alkylthioalkyl-" refers to the group alkyl-S-alk- wherein "alk" is an alkylene group. In "lower alkylthioalkyl-" each alkyl and alkylene is lower alkyl and alkylene, respectively.

The term "alkoxycarbonyloxy-" refers to alkyl-O-C(O)-O-.

The term "aryloxycarbonyloxy-" refers to aryl-O-C(O)-O-.

The term "alkylthiocarbonyloxy-" refers to alkyl-S-C(O)-O-.

The term "amido" refers to the NR_2 group next to an acyl or sulfonyl group as in NR_2-C(O)-, RC(O)-NR^1-, NR_2-S(=O)$_2$- and RS(=O)$_2$-NR^1-, where R and R^1 include -H, alkyl, aryl, aralkyl, and heterocycloalkyl.

The term "carboxamido" refer to NR_2-C(O)- and RC(O)-NR^1-, where R and R^1 include -H, alkyl, aryl, aralkyl, and heterocycloalkyl. The term does not include urea, -NR-C(O)-NR-.

The terms "sulphonamido" or "sulfonamido" refer to NR_2-S(=O)$_2$- and RS(=O)$_2$-NR^1-, where R and R^1 include -H, alkyl, aryl, aralkyl, and heterocycloalkyl. The term does not include sulfonylurea, -NR-S(=O)$_2$-NR-.

The term "carboxamidoalkylaryl" and "carboxamidoaryl" refers to an aryl-alk-NR^1-C(O), and ar-NR^1-C(O)-alk-, respectively where "ar" is aryl, "alk" is alkylene, R^1 and R include H, alkyl, aryl, aralkyl, and heterocycloalkyl.

The term "sulfonamidoalkylaryl" and "sulfonamidoaryl" refers to an aryl-alk-NR^1-S(=O)$_2$-, and ar-NR^1-S(=O)$_2$-, respectively where "ar" is aryl, "alk" is alkylene, R^1 and R include -H, alkyl, aryl, aralkyl, and heterocycloalkyl.

The term "hydroxyalkyl" refers to an alkyl group substituted with one -OH.

The term "haloalkyl" refers to an alkyl group substituted with one halo.

The term "cyano" refers to $-C\equiv N$.

The term "nitro" refers to -NO_2.

The term "acylalkyl" refers to an alkyl-C(O)-alk-, where "alk" is alkylene.

The term "aminocarboxamidoalkyl-" refers to the group NR_2-C(O)-N(R)-alk- wherein R is an alkyl group or H and "alk" is an alkylene group. "Lower aminocarboxamidoalkyl-" refers to such groups wherein "alk" is lower alkylene.

The term "heteroarylalkyl" refers to an alkylene group substituted with a heteroaryl group.

The term "perhalo" refers to groups wherein every C-H bond has been replaced with a C-halo bond on an aliphatic or aryl group. Suitable perhaloalkyl groups include -CF_3 and -$CFCl_2$.

The term "carboxylic acid moiety" refers to a compound having a carboxylic acid group (-COOH), and salts thereof, a carboxylic acid ester, or a carboxylic acid surrogate. Suitable carboxylic acid surrogates include a tetrazole group, a hydroxamic acid group, a thiazolidinedione group, an acylsulfonamide group, and a 6-azauracil; and prodrugs thereof. Phosphonic acids and prodrugs thereof are not within the scope of carboxylic acid surrogates.

The term "co-crystal" as used herein means a crystalline material comprised of two or more unique solids at room temperature, each containing distinctive physical characteristics, such as structure, melting point and heats of fusion. The co-crystals of the present invention comprise a co-crystal former H-bonded to a compound of the present invention. The co-crystal former may be H-bonded directly to the compound of the present invention or may be H-bonded to an additional molecule which is bound to the compound of the present invention. The additional molecule may be H-bonded to the compound of the present invention or bound ionically to the compound of the present invention. The additional molecule could also be a second API. Solvates of compounds of the present invention that do not further comprise a co-crystal former are not "co-crystals" according to the present invention. The co-crystals may however, include one or more solvate molecules in the crystalline lattice. That is, solvates of co-crystals, or a co-crystal further comprising a solvent or compound that is a liquid at room temperature, is included in the present invention as a co-crystal.

The co-crystals may also be a co-crystal between a co-crystal former and a salt of a compound of the present invention, but the compound of the present invention and the co-crystal former are constructed or bonded together through hydrogen bonds. Other modes of molecular recognition may also be present including, pi-stacking, guest-host complexation and van der Waals interactions. Of the interactions listed above, hydrogen-bonding is the dominant interaction in the formation of the co-crystal, (and a required interaction according to the present invention) whereby a non-covalent bond is formed between a hydrogen bond donor of one of the moieties and a hydrogen bond acceptor of the other.

Crystalline material comprised of solid compound of the present invention and one or more liquid solvents (at room temperature) are included in the present invention as "solvates." A "hydrate" is where the solvent is water. Other forms of the present invention include, but are not limited to, are anhydrous forms and de-solvated solvates.

The ratio of the compound of the present invention to co-crystal former or solvent may be specified as stoichiometric or non-stoichiometric. 1:1, 1.5:1, 1:1.5, 2:1, 1:2, and 1:3 ratios of API:co-crystal former/solvent are examples of stoichiometric ratios.

The term "binding" means the specific association of the compound of interest to the thyroid hormone receptor. One method of measuring binding in this invention is the ability of the compound to inhibit the association of ^{125}I-T3 with a mixture of thyroid hormone receptors using nuclear extracts or purified or partially purified thyroid hormone receptor (for example, alpha or beta) in a heterologous assay.

The term "energy expenditure" means basal or resting metabolic rate as defined by Schoeller *et al., J Appl Physiol.*;53(4):955-9 (1982). Increases in the resting metabolic rate can be also be measured using increases in O_2 consumption and/or CO_2 efflux and/or increases in organ or body temperature.

The phrase "therapeutically effective amount" means an amount of a compound or a combination of compounds that ameliorates, attenuates or eliminates one or more of the symptoms of a particular disease or condition or prevents, modifies, or delays the onset of one or more of the symptoms of a particular disease or condition.

The term "pharmaceutically acceptable salt" includes salts of compounds of Formula I and its prodrugs derived from the combination of a compound of this invention and an organic or inorganic acid or base. Suitable acids include acetic acid, adipic acid, benzenesulfonic acid, (+)-7,7-dimethyl-2-oxobicyclo[2.2.1]heptane-1-methanesulfonic acid, citric acid, 1,2-ethanedisulfonic acid, dodecyl sulfonic acid, fumaric acid, glucoheptonic acid, gluconic acid, glucuronic acid, hippuric acid, hydrochloride hemiethanolic acid, HBr, HCl, HI, 2-hydroxyethanesulfonic acid, lactic acid, lactobionic acid, maleic acid, methanesulfonic acid, methylbromide acid, methyl sulfuric acid, 2-naphthalenesulfonic acid, nitric acid, oleic acid, 4,4'-methylenebis [3-hydroxy-2-naphthalenecarboxylic acid], phosphoric acid, polygalacturonic acid, stearic acid, succinic acid, sulfuric acid, sulfosalicylic acid, tannic acid, tartaric acid, terphthalic acid, and *p*-toluenesulfonic acid.

The term "patient" means an animal.

The term "animal" includes birds and mammals, in one embodiment a mammal, including a dog, cat, cow, horse, goat, sheep, pig or human. In one embodiment the animal is a human.In another embodiment the animal is a male. In another embodiment the animal is a female.

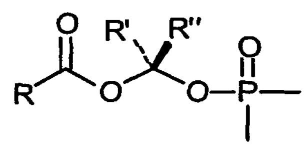
The term "prodrug" as used herein refers to any compound that when administered to a biological system generates a biologically active compound as a result of spontaneous chemical reaction(s), enzyme catalyzed chemical reaction(s), and/or metabolic chemical reaction(s), or a combination of each. Standard prodrugs are formed using groups attached to functionality, *e.g.*, HO-, HS-, HOOC-, R_2N-, associated with the drug, that cleave *in vivo*. Standard prodrugs include but are not limited to carboxylate esters where the group is alkyl, aryl, aralkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl as well as esters of hydroxyl, thiol and amines where the group attached is an acyl group, an alkoxycarbonyl, aminocarbonyl; phosphate or sulfate. The groups illustrated are exemplary, not exhaustive, and one skilled in the art could prepare other known varieties of prodrugs. Such prodrugs of the compounds of Formula I, fall within this scope. Prodrugs must undergo some form of a chemical transformation to produce the compound that is biologically active or is a precursor of the biologically active compound. In some cases, the prodrug is biologically active, usually less than the drug itself, and serves to improve drug efficacy or safety through improved oral bioavailability, and/or pharmacodynamic half-life, etc. Prodrug forms of compounds may be utilized, for example, to improve bioavailability, improve subject acceptability such as by masking or reducing unpleasant characteristics such as bitter taste or gastrointestinal irritability, alter solubility such as for intravenous use, provide for prolonged or sustained release or delivery, improve ease of formulation, or provide site-specific delivery of the compound. Prodrugs are described in The Organic Chemistry of Drug Design and Drug Action, by Richard B. Silverman, Academic Press, San Diego, 1992. Chapter 8: "Prodrugs and Drug delivery Systems" pp.352-401; Design of Prodrugs, edited by H. Bundgaard, Elsevier Science, Amsterdam, 1985; Design of Biopharmaceutical Properties through Prodrugs and Analogs, Ed. by E. B. Roche, American Pharmaceutical Association, Washington, 1977; and Drug Delivery Systems, ed. by R. L. Juliano, Oxford Univ. Press, Oxford, 1980.

The term "phosphonate prodrug" refers to compounds that breakdown chemically or enzymatically to a phosphonic acid group *in vivo*. As employed herein the term includes, but is not limited to, the following groups and combinations of these groups:

Acyloxyalkyl esters which are well described in the literature (Farquhar *et al.*, *J. Pharm. Sci.*, 72: 324-325 (1983)).

Other acyloxyalkyl esters are possible in which a cyclic alkyl ring is formed. These esters have been shown to generate phosphorus-containing nucleotides inside cells through a postulated sequence of reactions beginning with deesterification and followed by a series of elimination reactions (*e.g.*, Freed *et al.*, *Biochem. Pharm.*, 38: 3193-3198 (1989)).

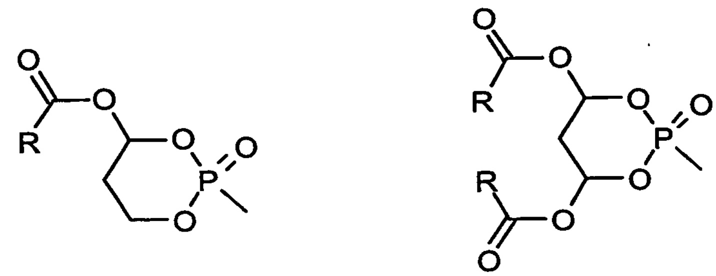
Another class of these double esters known as alkyloxycarbonyloxymethyl esters, as shown in formula A, where R is alkoxy, aryloxy, alkylthio, arylthio, alkylamino, and arylamino; R', and R" are independently -H, alkyl, aryl, alkylaryl, and heterocycloalkyl have been studied in the area of β-lactam antibiotics (Nishimura *et al.*, *J. Antibiotics*, 40(1): 81-90 (1987); for a review see Ferres, H., *Drugs of Today*, 19: 499 (1983)). More recently Cathy, M. S., *et al.* (Abstract from AAPS Western Regional Meeting, April, 1997) showed that these alkyloxycarbonyloxymethyl ester prodrugs on (9-[(R)-2-phosphonomethoxy)propyl]adenine (PMPA) are bioavailable up to 30% in dogs.



A.

wherein R, R', and R" are independently H, alkyl, aryl, alkylaryl, and alicyclic; (see WO 90/08155; WO 90/10636).

Other acyloxyalkyl esters are possible in which a cyclic alkyl ring is formed such as shown in formula B. These esters have been shown to generate phosphorus-containing nucleotides inside cells through a postulated sequence of reactions beginning with deesterification and followed by a series of elimination reactions (*e.g.*, Freed *et al.*, *Biochem. Pharm.*, 38: 3193-3198 (1989)).

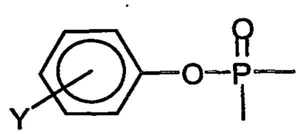


Formula B

wherein R is -H, alkyl, aryl, alkylaryl, alkoxy, aryloxy, alkylthio, arylthio, alkylamino, arylamino, or cycloalkyl.

Another class of these double esters known as alkyloxycarbonyloxymethyl esters, as shown in formula A, where R is alkoxy, aryloxy, alkylthio, arylthio, alkylamino, and arylamino; R', and R" are independently -H, alkyl, aryl, alkylaryl, and heterocycloalkyl have been studied in the area of β-actam antibiotics (Nishimura *et al., J. Antibiotics*, 40(1): 81-90 (1987); for a review see Ferres, H., *Drugs of Today*, 19: 499 (1983)). More recently Cathy, M. S., *et al.* (Abstract from AAPS Western Regional Meeting, April, 1997) showed that these alkyloxycarbonyloxymethyl ester prodrugs on (9-[(R)-2-phosphonomethoxy)propyl]adenine (PMPA) are bioavailable up to 30% in dogs.

Aryl esters have also been used as phosphonate prodrugs (*e.g.*, DeLambert *et al., J. Med. Chem.* 37(7): 498-511 (1994); Serafinowska *et al., J. Med. Chem.* 38(8): 1372-9 (1995). Phenyl as well as mono and poly-substituted phenyl proesters have generated the parent phosphonic acid in studies conducted in animals and in man (Formula C). Another approach has been described where Y is a carboxylic ester ortho to the phosphate (Khamnei *et al., J. Med. Chem.* 39: 4109-15 (1996)).

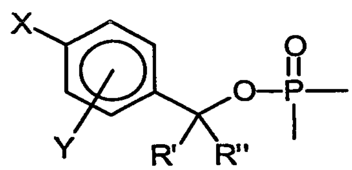


Formula C

wherein Y is -H, alkyl, aryl, alkylaryl, alkoxy, acyloxy, halogen, amino, alkoxycarbonyl, hydroxy, cyano, and heterocycloalkyl.

Benzyl esters have also been reported to generate the parent phosphonic acid. In some cases, using substituents at the *para*-position can accelerate the hydrolysis. Benzyl

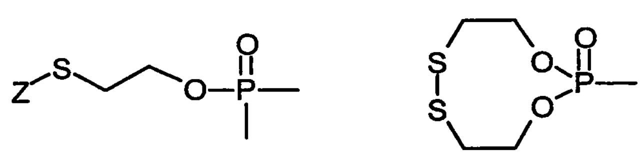
analogs with 4-acyloxy or 4-alkyloxy group [Formula D, X = -H, OR or O(CO)R or O(CO)OR] can generate the 4-hydroxy compound more readily through the action of enzymes, *e.g.*, oxidases, esterases, etc. Examples of this class of prodrugs are described in Mitchell *et al., J. Chem. Soc. Perkin Trans.* I 2345 (1992); WO 91/19721.



Formula D

wherein X and Y are independently -H, alkyl, aryl, alkylaryl, alkoxy, acyloxy, hydroxy, cyano, nitro, perhaloalkyl, halo, or alkyloxycarbonyl; and R' and R'' are independently -H, alkyl, aryl, alkylaryl, halogen, and cyclic alkyl.

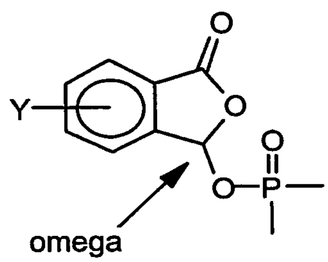
Thio-containing phosphonate proesters may also be useful in the delivery of drugs to hepatocytes. These proesters contain a protected thioethyl moiety as shown in formula E. One or more of the oxygens of the phosphonate can be esterified. Since the mechanism that results in de-esterification requires the generation of a free thiolate, a variety of thiol protecting groups are possible. For example, the disulfide is reduced by a reductase-mediated process (Puech *et al., Antiviral Res.* 22: 155-174 (1993)). Thioesters will also generate free thiolates after esterase-mediated hydrolysis Benzaria, *et al., J. Med. Chem.*, 39(25): 4958-65 (1996)). Cyclic analogs are also possible and were shown to liberate phosphonate in isolated rat hepatocytes. The cyclic disulfide shown below has not been previously described and is novel.



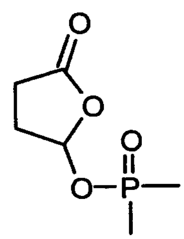
Formula E

wherein Z is alkylcarbonyl, alkoxycarbonyl, arylcarbonyl, aryloxycarbonyl, or alkylthio.

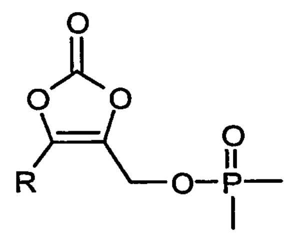
Other examples of suitable prodrugs include proester classes exemplified by Biller and Magnin (U.S. 5,157,027); Serafinowska *et al., J. Med. Chem,.* 38(8): 1372-9 (1995); Starrett *et al., J. Med. Chem*, 37: 1857 (1994); Martin *et al. J. Pharm. Sci.* 76: 180 (1987); Alexander *et al., Collect. Czech. Chem. Commun,* 59: 1853 (1994); and EP 0 632 048 A1. Some of the structural classes described are optionally substituted, including fused lactones attached at the omega position (formulae E-1 and E-2) and optionally substituted 2-oxo-1,3-dioxolenes attached through a methylene to the phosphorus oxygen (formula E-3) such as:



3-phthalidyl
E-1



2-oxotetrahydrofuran-5-yl
E-2



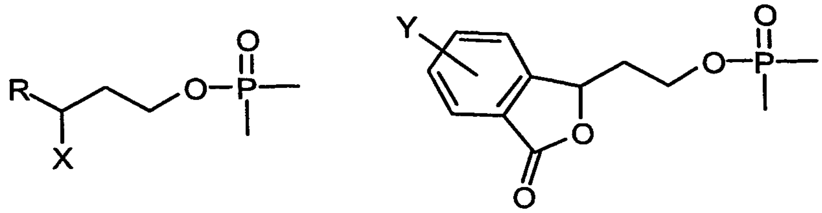
2-oxo-4,5-didehydro-1,3-dioxolanemethyl
E-3

wherein R is -H, alkyl, cycloalkyl, or heterocycloalkyl; and

wherein Y is -H, alkyl, aryl, alkylaryl, cyano, alkoxy, acyloxy, halogen, amino, heterocycloalkyl, and alkoxycarbonyl.

The prodrugs of Formula E-3 are an example of "optionally substituted heterocycloalkyl where the cyclic moiety contains a carbonate or thiocarbonate."

Propyl phosphonate proesters can also be used to deliver drugs into hepatocytes. These proesters may contain a hydroxyl and hydroxyl group derivatives at the 3-position of the propyl group as shown in formula F. The R and X groups can form a cyclic ring system as shown in formula F. One or more of the oxygens of the phosphonate can be esterified.



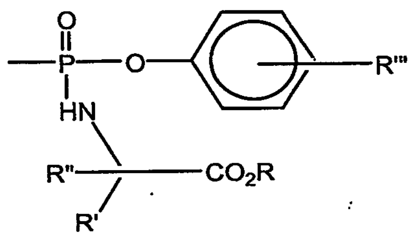
Formula F

wherein R is alkyl, aryl, heteroaryl;

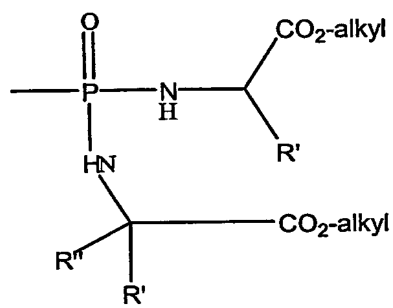
X is hydrogen, alkylcarbonyloxy, alkyloxycarbonyloxy; and

Y is alkyl, aryl, heteroaryl, alkoxy, alkylamino, alkylthio, halogen, hydrogen, hydroxy, acyloxy, amino.

Phosphoramidate derivatives have been explored as phosphate prodrugs (*e.g.*, McGuigan *et al.*, *J. Med. Chem.*, 42: 393 (1999) and references cited therein) as shown in Formula G and H.



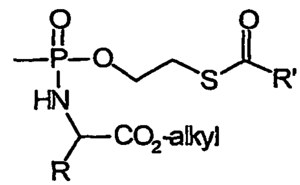
Formula G



Formula H

Cyclic phosphoramidates have also been studied as phosphonate prodrugs because of their speculated higher stability compared to non-cyclic phosphoramidates (*e.g.*, Starrett *et al.*, *J. Med. Chem.*, 37: 1857 (1994)).

Another type of phosphoramidate prodrug was reported as the combination of S-acyl-2-thioethyl ester and phosphoramidate (Egron *et al.*, *Nucleosides & Nucleotides*, 18, 981 (1999)) as shown in Formula J:

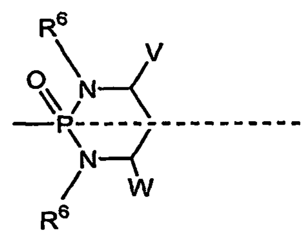


Formula J

Other prodrugs are possible based on literature reports such as substituted ethyls for example, bis(trichloroethyl)esters as disclosed by McGuigan, *et al., Bioorg Med. Chem. Lett.*, 3:1207-1210 (1993), and the phenyl and benzyl combined nucleotide esters reported by Meier, C. *et al., Bioorg. Med. Chem. Lett.* 7:99-104 (1997).

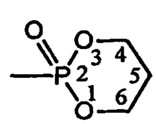
Other prodrugs are possible based on literature reports such as substituted ethyls for example, bis(trichloroethyl)esters as disclosed by McGuigan, *et al., Bioorg Med. Chem. Lett.*, 3:1207-1210 (1993), and the phenyl and benzyl combined nucleotide esters reported by Meier, C. *et al., Bioorg. Med. Chem. Lett.* 7:99-104 (1997).

The structure

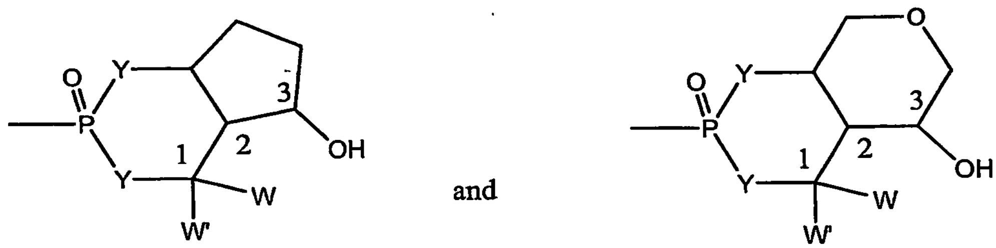


has a plane of symmetry running through the phosphorus-oxygen double bond when R^6=R^6, V=W, and V and W are either both pointing up or both pointing down. The same is true of structures where each -NR^6 is replaced with -O-.

The term "cyclic phosphonate ester of 1,3-propane diol", "cyclic phosphonate diester of 1,3-propane diol", "2 oxo 2λ^5 [1,3,2] dioxaphosphonane", "2 oxo [1,3,2] dioxaphosphonane", "dioxaphosphonane" refers to the following:

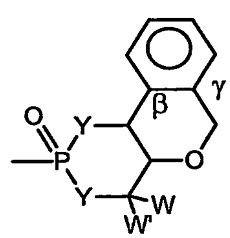


The phrase "together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, optionally containing 1 heteroatom, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy, alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus" includes the following:

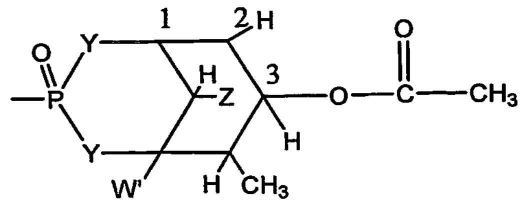


The structure shown above (left) has an additional 3 carbon atoms that forms a five member cyclic group. Such cyclic groups must possess the listed substitution to be oxidized.

The phrase "together V and Z are connected via an additional 3-5 atoms to form a cyclic group, optionally containing one heteroatom, that is fused to an aryl group attached at the beta and gamma position to the Y attached to the phosphorus" includes the following:

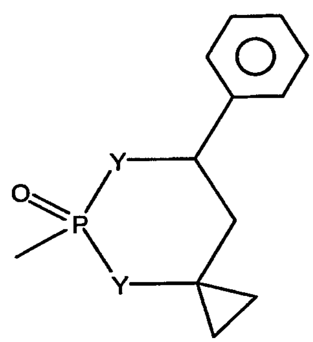


The phrase "together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said additional carbon atoms that is three atoms from a Y attached to the phosphorus" includes the following:



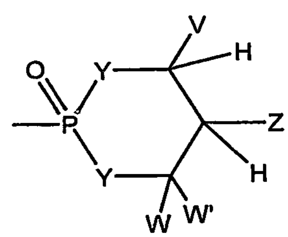
The structure above has an acyloxy substituent that is three carbon atoms from a Y, and an optional substituent, $-CH_3$, on the new 6-membered ring. There has to be at least one hydrogen at each of the following positions: the carbon attached to Z; both carbons alpha to the carbon labeled "3"; and the carbon attached to "$OC(O)CH_3$" above.

The phrase "together W and W' are connected via an additional 2-5 atoms to form a cyclic group, optionally containing 0-2 heteroatoms, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl" includes the following:



The structure above has V=aryl, and a spiro-fused cyclopropyl group for W and W'.

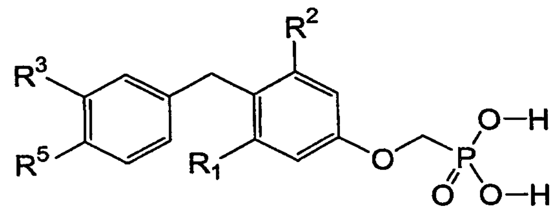
The term "cyclic phosphon(amid)ate" refers to



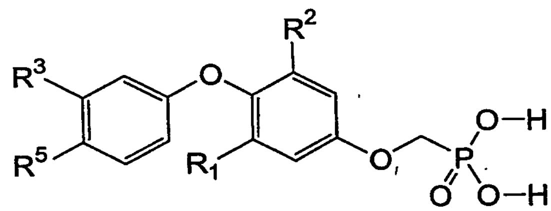
where Y is independently -O- or $-NR^V-$. The carbon attached to V must have a C-H bond. The carbon attached to Z must also have a C-H bond.

The naming of the compounds is done by having the ring bearing the groups R^5 and R^3 be a substituent on the ring bearing the R^1 and R^2 groups. The naming of the prodrugs is done by having the diaryl system with its linker T (Formula I or III) or D (Formula II) be a substituent on the phosphorus atom contained in X. For example:

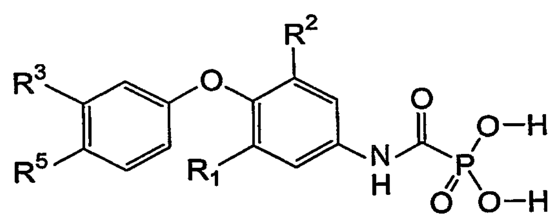
[3-R^1-5-R^2-4-(4'-R^5-3'-R^3-benzyl)phenoxy]methylphosphonic acid represents the formula:



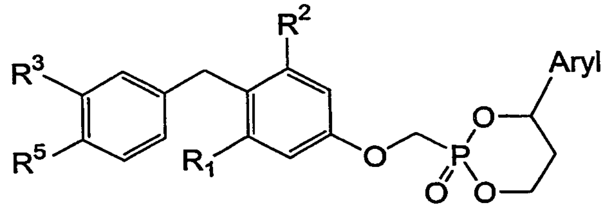
[3-R^1-5-R^2-4-(4'-R^5-3'-R^3-phenoxy)phenoxy]methylphosphonic acid represents the formula:



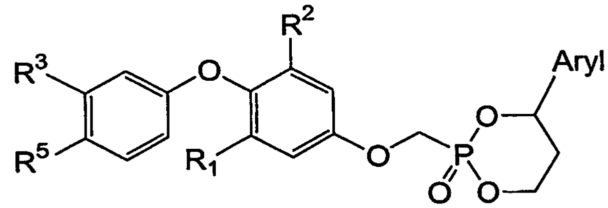
N-[3-R^1-5-R^2-4-(4'-R^5-3'-R^3-phenoxy)phenyl]carbamoylphosphonic acid represents the formula:



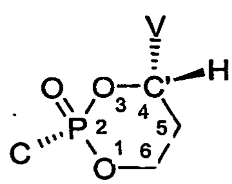
2-[(3-R^1-5-R^2-4-(4'-R^5-3'-R^3-benzyl)phenoxy)methyl]-4-aryl-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane:



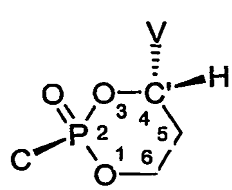
2-[(3-R^1-5-R^2-4-(4'-R^5-3'-R^3-phenoxy)phenoxy)methyl]-4-aryl-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane:



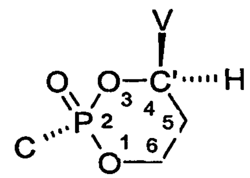
The term "*cis*" stereochemistry refers to the spatial relationship of the V group and the carbon attached to the phosphorus atom on the six-membered ring. The formula below shows a *cis* stereochemistry.



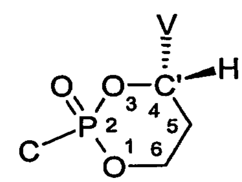
The term "*trans*" stereochemistry refers to the spatial relationship of the V group and the carbon, attached to the phosphorus atom, on the six-membered ring. The formula below shows a *trans*-stereochemistry.



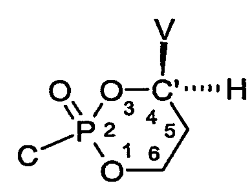
The formula below shows another *trans*-stereochemistry.



The terms "*S*-configuration", "*S*-isomer" and "*S*-prodrug" refers to the absolute configuration *S* of carbon C'. The formula below shows the *S*-stereochemistry.



The terms "*R*-configuration", "*R*-isomer" and "*R*-prodrug" refers to the absolute configuration *R* of carbon C'. The formula below shows the *R*-stereochemistry.



The term "percent enantiomeric excess (% ee)" refers to optical purity. It is obtained by using the following formula:

$$\frac{[R] - [S]}{[R] + [S]} \times 100 = \%R - \%S$$

where [R] is the amount of the R isomer and [S] is the amount of the S isomer. This formula provides the % ee when R is the dominant isomer.

The term "enantioenriched" or "enantiomerically enriched" refers to a sample of a chiral compound that consists of more of one enantiomer than the other. The extent to which a sample is enantiomerically enriched is quantitated by the enantiomeric ratio or the enantiomeric excess.

The term "liver" refers to liver organ.

The term "enhancing" refers to increasing or improving a specific property.

The term "liver specificity" refers to the ratio:

$$\frac{[\text{drug or a drug metabolite in liver tissue}]}{[\text{drug or a drug metabolite in blood or another tissue}]}$$

as measured in animals treated with the drug or a prodrug. The ratio can be determined by measuring tissue levels at a specific time or may represent an AUC based on values measured at three or more time points.

The term "phosphonic acid containing compounds" refers to compounds that contain PO_3H_2 or PO_3^{-2}.

The term "inhibitor of fructose-1,6-biphosphatase" or "FBPase inhibitor" refers to compounds that inhibit FBPase enzyme activity and thereby block the conversion of fructose 1,6-bisphosphate, the substrate of the enzyme, to fructose 6-phosphate. These compounds have an IC_{50} of equal to or less than 50 μM on human liver FBPase measured according to the procedure found in US 6,489,476.

The term "increased or enhanced liver specificity" refers to an increase in the liver specificity ratio in animals treated with a compound of the present invention and a control compound. In one embodiment the test compound is a phonsphonic acid compound of the present invention and in another embodiment the test compound is a prodrug thereof. In one embodiment the control compound is a phonsphonic acid compound of the present invention. In another embodiment the control compound is the corresponding carboxylic acid derivative of the phosphonic acid test compound.

The term "enhanced oral bioavailability" refers to an increase of at least 50% of the absorption of the dose of the parent drug, unless otherwise specified. In an additional aspect the increase in oral bioavailability of the prodrug (compared to the parent drug) is at least 100%, that is a doubling of the absorption. Measurement of oral bioavailability usually refers to measurements of the prodrug, drug, or drug metabolite in blood, plasma, tissues, or urine following oral administration compared to measurements following systemic administration of the compound administered orally.

The terms "treating" or "treatment" of a disease includes a slowing of the progress or development of a disease after onset or actually reversing some or all of the disease affects. Treatment also includes palliative treatment.

The term "preventing" includes a slowing of the progress or development of a disease before onset or precluding onset of a disease.

The term "thyroid hormone receptors" (TR) refers to intracellular proteins located in cell nuclei that, following the binding of thyroid hormone, stimulate transcription of specific genes by binding to DNA sequences called thyroid hormone response elements (TREs). In this manner TR regulates the expression of a wide variety of genes involved in metabolic processes (*e.g.*, cholesterol homeostasis and fatty acid oxidation) and growth and development in many tissues, including liver, muscle and heart. There are at least two forms of TR; TR alpha (on chromosome 17) and TR beta (on chromosome 3). Each of these isoforms also has two main isoforms: TR alpha-1 and TR alpha-2; and TR beta-1 and TR beta-2, respectively. TRs are high affinity receptors for thyroid hormones, especially triiodothyronine.

The term "ACC" refers to acetyl CoA carboxylase.

The term "FAS" refers to fatty acid synthase.

The term "spot-14" refers to a 17 kilodalton protein expressed in lipogenic tissues and is postulated to play a role in thyroid hormone stimulation of lipogenesis. (Campbell, MC *et al., Endocriniology* 10: 1210 (2003).

The term "CPT-1" refers to carnitine palmitoyltransferase-1.

The term "CYP7A" refers to Cholesterol 7-alpha hydroxylase, which is a membrane-bound cytochrome P450 enzyme that catalyzes the 7-alpha-hydroxylation of cholesterol in the presence of molecular oxygen and NADPH-ferrihemoprotein reductase. This enzyme, encoded by CYP7, converts cholesterol to 7-alpha-hydroxycholesterol which is the first and rate-limiting step in the synthesis of bile acids.

The term "apoAI" refers to Apolipoprotein AI found in HDL and chylomicrons. It is an activator of LCAT and a ligand for the HDL receptor.

The term "mGPDH" refers to mitochondrial glycerol-3-phosphate dehydrogenase.

The term "hypercholesterolemia" refers to presence of an abnormally large amount of cholesterol in the cells and plasma of the circulating blood.

The term "hyperlipidemia" or "lipemia" refers to the presence of an abnormally large amount of lipids in the circulating blood.

The term "atherosclerosis" refers to a condition characterized by irregularly distributed lipid deposits in the intima of large and medium-sized arteries wherein such deposits provoke fibrosis and calcification. Atherosclerosis raises the risk of angina, stroke, heart attack, or other cardiac or cardiovascular conditions.

The term "obesity" refers to the condition of being obese. Being obese is defined as a BMI of 30.0 or greater; and extreme obesity is defined at a BMI of 40 or greater. "Overweight" is defined as a body mass index of 25.0 to 29.9 (This is generally about 10 percent over an ideal body weight)

The term "coronary heart disease" or "coronary disease" refers to an imbalance between myocardial functional requirements and the capacity of the coronary vessels to supply sufficient blood flow. It is a form of myocardial ischemia (insufficient blood supply to the heart muscle) caused by a decreased capacity of the coronary vessels.

The term "diabetes" refers to a heterogeneous group of disorders that share glucose intolerance in common. It refers to disorders in which carbohydrate utilization is reduced and that of lipid and protein enhanced; and may be characterized by hyperglycemia, glycosuria, ketoacidosis, neuropathy, or nephropathy.

The term "non-insulin-dependent diabetes mellitus" (NIDDM or type 2 diabetes) refers to a heterogeneous disorder characterized by impaired insulin secretion by the pancreas and insulin resistance in tissues such as the liver, muscle and adipose tissue. The manifestations of the disease include one or more of the following: impaired glucose tolerance, fasting hyperglycemia, glycosuria, increased hepatic glucose output, reduced hepatic glucose uptake and glycogen storage, reduced whole body glucose uptake and utilization, dyslipidemia, fatty liver, ketoacidosis, microvascular diseases such as retinopathy, nephropathy and neuropathy, and macrovascular diseases such as coronary heart disease.

The term "impaired glucose tolerance (IGT)" refers to a condition known to precede the development of overt type 2 diabetes. It is characterized by abnormal blood glucose excursions following a meal. The current criteria for the diagnosis of IGT are based on 2-h plasma glucose levels post a 75g oral glucose test (144-199 mg/dL). Although variable from population to population studied, IGT progresses to full blown NIDDM at a rate of 1.5 to 7.3% per year, with a mean of 3-4% per year. Individuals with IGT are believed to have a 6 to 10-fold increased risk in developing NIDDM. IGT is an independent risk factor for the development of cardiovascular disease.

The term "Non-Alcoholic SteatoHepatitis (NASH)"refers to an inflammatory condition of the liver characterized by fat accumulation, hepatocellular injury, and fibrosis or cirrhosis, and may affect 2-3 percent of adults in Western countries. NASH is preceded by non-alcoholic fatty liver disease, or NAFLD, which is characterized by fat accumulation in the liver and mild liver injury. The pathogenesis of NASH is

multifactorial. Insulin resistance as well as the resulting hyperinsulinemia may be important factors in the accumulation of hepatocellular fat, whereas excess intracellular fatty acids, oxidant stress, adenosine triphosphate depletion, and mitochondrial dysfunction may be important causes of hepatocellular injury and the development of an inflammatory condition in the steatotic liver. NASH is frequently but not always associated with severe obesity and is intimately related to clinical and biological markers of the insulin resistance syndrome. The accumulation of fat in the liver is thought to contribute significantly to the development of hepatic insulin resistance.

The term "insulin resistance" is defined clinically as the impaired ability of a known quantity of exogenous or endogenous insulin to increase whole body glucose uptake and utilization. As insulin regulates a wide variety of metabolic processes in addition to glucose homeostasis (*e.g.*, lipid and protein metabolism), the manifestations of insulin resistance are diverse and include one or more of the following: glucose intolerance, hyperinsulinemia, a characteristic dyslipidemia (high triglycerides; low high-density lipoprotein cholesterol, and small, dense low-density lipoprotein cholesterol), obesity, upper-body fat distribution, fat accumulation in the liver (non-alcoholic fatty liver disease), NASH (non-alcoholic steatohepatitis), increased hepatic glucose output, reduced hepatic glucose uptake and storage into glycogen, hypertension, and increased prothrombotic and antifibrinolytic factors. This cluster of cardiovascular-metabolic abnormalities is commonly referred to as "The Insulin Resistance Syndrome" or "The Metabolic Syndrome" and may lead to the development of type 2 diabetes, accelerated atherosclerosis, hypertension or polycystic ovarian syndrome.

The Metabolic Syndrome" or "Metabolic Syndrome X"is characterized by a group of metabolic risk factors in one person. They include:

- Central obesity (excessive fat tissue in and around the abdomen)
- Atherogenic dyslipidemia (blood fat disorders — mainly high triglycerides and low HDL cholesterol — that foster plaque buildups in artery walls)
- Raised blood pressure (130/85 mmHg or higher)
- Insulin resistance or glucose intolerance (the body can't properly use insulin or blood sugar)
- Prothrombotic state (*e.g.*, high fibrinogen or plasminogen activator inhibitor [–1] in the blood)
- Proinflammatory state (*e.g.*, elevated high-sensitivity C-reactive protein in the blood)

According to the present invention, "Metabolic Syndrome" or "Metabolic Syndrome X" is identified by the presence of three or more of these components:

- Central obesity as measured by waist circumference:

Men: Greater than 40 inches

Women: Greater than 35 inches

- Fasting blood triglycerides greater than or equal to 150 mg/dL
- Blood HDL cholesterol:
- Men: Less than 40 mg/dL
- Women: Less than 50 mg/dL
- Blood pressure greater than or equal to 130/85 mmHg
- Fasting glucose greater than or equal to 110 mg/dL

The term "thyroid responsive element" or "TRE" refers to an element that usually consists of directly repeated half-sites with the consensus sequence AGGTCA. (Harbers *et al., Nucleic Acids Res.* 24 (12): 2252–2259 (1996)). TREs contain two half-sites of the AGG TCA motif which can be arranged as direct repeats, inverted repeats, or everted repeats.

The term "thyroid responsive genes" refers to genes whose expression is affected by triiodothyronine (Menjo *et al., Thyroid* 9(9):959-67 (1999); Helbing *et al., Mol. Endocrinol.* 17(7): 1395-409 (2003)).

The term "TSH" or "thyrotropin" refers to the thyroid stimulating hormone.

The term "atherogenic proteins" refers to proteins that induce, stimulate, enhance or prolong atherosclerosis and diseases related to atherosclerosis, including but not limited to coronary heart disease. Atherogenic proteins include apoAI and Lp (a).

The term "thyroid hormone, or TH" includes for example natural iodinated thyronines from thyroglobulin (*e.g.*, T3, T4), as well as drugs such as Levothyroxine sodium which is the sodium salt a levorotatory isomer of T4 and a commonly used drug as replacement therapy in hypothyroidism. Other uses include the treatment of simple nonendemic goiter, chronic lymphocytic thyroiditis and thyrotropin-dependent thyroid carcinoma. Liothyronine sodium is the sodium salt a levorotatory isomer of T3. Liotrix is a 4:1 mixture of levothyroxine and liothronine. Thyroid is a preparation derived from dried and defatted thyroid glands of animals.

The term "thyromimetic" or "T3 mimetic" as used herein, is intended to cover any moiety which binds to a thyroid receptor and acts as an agonists, antagonists or partial agonists/antagonist of T3. The thyromimetic may be further specified as a,

agonists, an antagonists, a partial agonists, or a partial antagonist. The thyromimetics of the present invention presumably bind the T3 binding site and can inhibit T3 binding to a thyroid hormone receptor utilizing a heterologous displacement reaction. Thyromimetics of the present invention that can produce one of or more of the effects mediated by naturally occurring L-triiodothyronine in a target tissue or cell would be considered an agonist or partial agonist. Thyromimetics of the present invention that can inhibit one of more of the effects mediated by naturally occurring L-triiodothyronine in a target tissue or cell would be considered an antagonist, partial agonist, or inverse agonist.

The term "metabolic disease" includes diseases and conditions such as obesity, diabetes and lipid disorders such as hypercholesterolemia, hyperlipidemia, hypertriglyceridemia as well as disorders that are associated with abnormal levels of lipoproteins, lipids, carbohydrates and insulin such as metabolic syndrome X, diabetes, impaired glucose tolerance, atherosclerosis, coronary heart disease, cardiovascular disease.

The term "mitochondrial biogenesis" or "mitochondrialgenesis" refers to the rate at which nascent mitochondria are synthesized. Mitochondrial biogenesis that occurs during cell replication provides enough new mitochondria for both the parent and daughter cells. Mitochondrial biogenesis that occurs in the absence of cell replication leads to an increase in the number of mitochondria within a cell.

As used herein, the term "significant" or "statistically significant" means a result (*i.e.* experimental assay result) where the p-value is $\leq$ 0.05 (*i.e.* the chance of a type I error is less than 5%) as determined by an art-accepted measure of statistical significance appropriate to the experimental design.

All references cited herein are incorporated by reference in their entirety.

DETAILED DESCRIPTION

The present invention relates to methods of preventing or treating metabolic diseases with phosphonic acid containing compounds, pharmaceutically acceptable salts and prodrugs thereof, and pharmaceutically acceptable salts of the prodrugs, where the phosphonic acid containing compounds bind to a thyroid hormone receptor.

Thyroid hormones and thyroid hormone mimetics bind to thyroid hormone receptors in the nucleus of cells and can change expression levels of genes encoding proteins that play an important role in metabolic diseases. Metabolic diseases that can be prevented or treated with thyroid hormone mimetics include obesity and lipid disorders

such as hypercholesterolemia, hyperlipidemia, and hypertriglyderidemia as described in further detail below. Other metabolic diseases that can be prevented or treated with thyroid hormone mimetics include NASH, diabetes, impaired glucose tolerance, and insulin resistance. Conditions associated with these diseases, such as atherosclerosis, coronary artery disease, and heart failure, can also be treated with these thyroid hormone receptor binding compounds.

Prior to the discoveries of the present invention, phosphonic acids were thought to be a poor replacement for carboxylic acids based on differences in geometry, size, and charge. Phosphonic acids can also show reduced binding affinities against enzymes that utilize or bind the analogous carboxylic acid. Phosphonic acids can also display differences in cellular and *in vivo* potency, oral bioavailability, pharmacokinetics, metabolism, and safety. T3 and previously reported T3 mimetics contain a carboxylic acid thought to be important for binding and activation of T3 responsive genes. The carboxylic acid may also be important in the transport and distribution of these compounds through various transport proteins. Transport proteins can enhance transport of certain compounds, particularly negatively charged compounds, to the nucleus.

Prior to the discoveries of the present invention it was therefore unclear whether replacement of a carboxylic acid with a phosphonic acid would produce a compound that is effacious as a T3 mimetic because of the following:

1. it was not known whether a T3 mimetic with a phosphonic acid in place of the carboxylic acid would transported into liver cell across the celluar membrane;

2. if the phosphonic acid containing T3 mimetic were transported across the cellular membrane of liver cells, it was not known whether the compound would be transported across the nuclear membrane into the nucleus;

3. if the phosphonic acid containing T3 mimetic were transported across both the cellular membrane and the nuclear membrane of the liver cell, it was not known if the compound would bind to the TR receptor with a great enough affinity to be effacious;

4. if the phosphonic acid containing T3 mimetic were transported across both the cellular membrane and the nuclear membrane of the liver cell, and bound to the TR receptor with sufficient affinity for receptor activity, it was not known whether the compound would act as an agonist or antagonist of receptor activity;

5. if the if the phosphonic acid containing T3 mimetic were transported across both the cellular membrane and the nuclear membrane of the liver cell, and bound to the TR receptor with sufficient affinity for receptor activation, and acted as an agonist of

receptor activity, it was unknown whether the compound would have a high enough tissue selectivity and have a therapeutic index great enough to be efficacous in treating the diseases and disorders described herein while avoiding undesired side-effects involving the heart.

6. finally, even if the if the phosphonic acid containing T3 mimetic were transported across both the cellular membrane and the nuclear membrane of the liver cell, and bound to the TR receptor with sufficient affinity for receptor activation, and acted as an agonist of receptor activity, and have a high enough tissue selectivity and have a therapeutic index great enough to be efficacous in treating the diseases and disorders described herein while avoiding undesired side-effects involving the heart, it was not known if the phosphonic acid containing compounds of the present invention would be rapidly cleared from the blood by the kidneys thereby making the compound less useful as a drug compound.

Thus, it was unexpected when the present Inventors discovered that the phosphonic acid- T3 mimetic compounds of the present invention are capable of being effectively transported across the cellular membrane into liver cells and across the nuclear membrane where they bind the thyroid receptors and activate thyroid hormone responsive genes. Further, surprisingly the present Inventors discovered that the compounds of the present invention bind to the thyroid receptors with sufficient binding affinity to be effective in activating the receptors. Still further surprisingly, the present Inventors discovered that the compounds of the present invention act as agonists rather than antagonists and are thus effective in activating thyroid hormone responsive genes and for the uses described herein, such as lowering cholesterol. Still further surprisingly, the present Inventors discovered that the compounds of the present invention are effective in activating thyroid hormone responsive genes and for the uses described herein, such as lowering cholesterol, even for compounds of the present invention that bind to the thyroid hormone receptors with reduced affinity as compared to the corresponding carboxylic acid derivative. Still further surprisingly, the present Inventors discovered that the compounds of the present invention have a high enough tissue selectivity and have a therapeutic index great enough to be efficacous in treating the diseases and disorders described herein while avoiding undesired side-effects involving the heart.

It is well known that many phonphosic acids in the blood are quickly cleared by the kidneys thereby greatly dimishing there usefulness as drugs in many cases. When the

Inventors of the present invention discovered that prodrugs of the compounds of the present invention were excreted into the blood stream as active phosphonic acids after being processed in the liver, it was not known whether the active compound would be quickly cleared by the kidneys or whether the phosphonic acid would be re-absorbed or transported into the liver. It was therefore unexpected when the the present Inventors discovered that the active phosphonic acid compounds of the present invention were not rapidly cleared by the kidneys. It was also unexpected when the the present Inventors discovered that the active phosphonic acid compounds of the present invention were re-absorbed or transported back into the liver. In fact, it was surprisingly found that the liver was the main mode of clearance of compounds tested.

In one aspect, the phosphonic acid containing compounds, pharmaceutically acceptable salts and prodrugs thereof, and pharmaceutically acceptable salts of the prodrugs used in these methods bind to at least one thyroid hormone receptor with an Ki of ≤ 100 nM relative to T3, or ≤ 90nM, ≤ 80nM, ≤ 70nM, ≤ 60nM, ≤ 50nM, ≤ 40nM, ≤ 30nM, ≤ 20nM, ≤ 10nM, ≤ 50nM, ≤1nM, ≤ 0.5 nM. Thyroid hormone receptor binding is readily determined using assays described in the literature. For example, nuclear extracts from animal livers can be prepared according to the methods described by Yokoyama *et al.* (*J. Med. Chem.*, 38: 695-707 (1995)). Binding assays can also be performed using purified thyroid hormone receptors. For example, using the methods used by Chiellini *et al.* (*Bioorg. Med. Chem.*, 10: 333-346 (2002)) competition ligand binding affinities are determined using ^{125}IT3 and the human thyroid receptors TRα1 and TRβ1. The latter methods advantageously enable determination of thyroid receptor selectivity. Methods described in Example A were used to determine the binding of compounds of this invention.

In another aspect, the phosphonic acid containing compounds, pharmaceutically acceptable salts and prodrugs thereof, and pharmaceutically acceptable salts of the prodrugs used in these methods cause at least a 50%, 2 fold, 3 fold, 4 fold, 6 fold or 8 fold increase or decrease in the expression of one or more thyroid hormone-responsive genes. Changes in gene expression can be detected in cells or *in vivo*. Prodrugs of the phosphonic acids can increase cellular uptake but in some cases are poorly converted to the phosphonic acid due to low levels of the enzymes required for the conversion. Changes in gene expression *in vivo* require either the phosphonic acid of the invention to be taken up by the tissue following administration or for the prodrug remain intact after

administration long enough to distribute to the target organ and cell. Following distribution to the cell, enzymes responsible for cleaving the prodrug must act on the prodrug and convert it to the phosphonic acid. The phosphonic acid must then be able to be transported to the nucleus. If a portion of the phosphonic acid is excreted from the cell it must be retransported back across the cellular membrane and nuclear membrane. The prodrugs of the present invention that are activated in the liver and excreted by the liver as phosphonic acids comounds are retransported back across the cellular and nuclear membrane and into the nucleus. Despite the being excreted from the liver and having to be retransported into the nucleus and despite having reduced potency, *in vivo,* the phosphonic acids and their prodrugs led to suprisingly potent biological activity. This surprisingly high biological activity is attributed to the ability of the compounds of the present invention to modulate genes known to be regulated by T3. For example, mGPDH increased > 1.5-fold in the liver of an animal administered a 1 mg/kg dose of the drug.

The liver is a major target organ of thyroid hormone with an estimated 8% of the hepatic genes regulated by thyroid hormone. Quantitative fluorescent-labeled cDNA microarray hybridization was used to identify thyroid-responsive genes in the liver as shown in Table 1 below (Feng *et al.*, *Mol. Endocrinol.*, 14: 947-955 (2000)). Hepatic RNA from T3-treated and hypothyroid mice were used in the study. Thyroid hormone treatment affected the expression of 55 genes from the 2225 different mouse genes sampled with 14 increasing >2-fold and 41 decreasing >60%.

TABLE 1

GENES REGULATED BY T3

List of Hepatic Genes Regulated by T3 Determined by cDNA Microarray Analyses			
Function Clone ID	Genes	Accession No.	Fold
Carbohydrate and fatty acid metabolism, and insulin action			
580906	*Spot 14 gene*	*X95279*	*8.8*
523120	*Glucose-6-phosphatase*	*U00445*	*3.8*
615159	*Carbonyl reductase (Cbr1)*	*U31966*	*3.3*
571409	*Insulin-like growth factor binding protein 1 precursor*	*X81579*	*3.0*
481636	*Fatty acid transport protein (FATP)*	*U15976*	*1.8*
550993	Cyp4a-10	X69296	0.3
583329	PHAS-II	U75530	0.3
616283	Serine/threonine kinase (Akt2)	U22445	0.3
583333	Putative transcription factor of the insulin gene	X17500	0.3
533177	Nuclear-encoded mitochondrial acyltransferase	L42996	0.2
608607	Glycerophosphate dehydrogenase	J02655	0.3
Cell proliferation, Replication			
614275	*B61*	*U26188*	*2.3*
597868	*Bcl-3*	*M90397*	*2.5*
493127	*Kinesin-like protein (Kip1p)*	*AF131865*	*2.0*
582689	Chromodomain-helicase-DNA binding protein CHD-1	P40201	0.4
524471	NfiB1-protein (exon 1–12)	Y07685	0.3
516208	Putative ATP-dependent RNA helicase PL10	J04847	0.3
558121	Murine vik5variant in the kinase	S53216	0.1
573247	C11 protein	X81624	0.3
522108	Thymic stromal stimulating factor	D43804	0.3
613942	Ubiquitin-activating enzyme E1 X	D10576	0.3
Signal transduction			
573046	*β-2 Adrenergic receptor*	*X15643*	*3.4*
583258	*Protein kinase C inhibitor (mPKCI)*	*U60001*	*2.1*
616040	Inhibitory G protein of adenylate cyclase, α chain	M13963	0.3
583353	Terminal deoxynucleotidyltransferase	04123	0.3
550956	Rho-associated, coiled-coil forming protein kinase p160	U58513	0.2
582973	Protein kinase C, Θ type	AB011812	0.3
442989	Protein kinase ζ	M94632	0.5
607870	Lamin A	D13181	0.3
Glycoprotein synthesis			
375144	α-2,3-Sialyltransferase	D28941	0.3
481883	β-Galactoside α 2,6-sialyltransferase	D16106	0.3
Cellular immunity			
615872	T-complex protein 1, d subunit	P80315	0.3
618426	H-2 class I histocompatibility antigen	Q61147	0.3
614012	FK506-binding protein (FKBP65)	L07063	0.3
604923	FK506-binding protein (FKBP23)	AF040252	0.2
Cytoskeletal protein			
374030	*Myosin binding protein H (MyBP-H)*	*U68267*	*2.2*

613905	AM2 receptor	X67469	0.3
616518	Cytoskeletal β-actin	X03672	0.3
614948	Actin, α cardiac	M15501	0.3
607364	Skeletal muscle actin	M12866	0.3
597566	Capping protein a-subunit	G565961	0.3
483226	Actin, γ-enteric smooth muscle	M26689	0.3
Others			
552837	Major urinary protein 2 precursor	M27608	3.9
521118	*β-Globin*	*AB020013*	*2.3*
493218	*α-Globin*	*L75940*	*2.7*
585883	Putative SH3-containing protein SH3P12	AF078667	0.3
615239	Membrane-type matrix metalloproteinase	X83536	0.2
402408	ece1 (endothelin-converting enzyme)	W78610	0.2
635768	α-Adaptin	P17426	0.3
634827	Glucose regulated protein 78	D78645	0.3
616189	Lupus la protein homolog	L00993	0.3
588337	EST	AI646753	0.4
335579	Virus-like (VL30) retrotransposon BVL-1	X17124	0.3
557037	TGN38B	D50032	0.3
597390	Mitochondrial genome	L07096	0.4
616563	Arylsulfatase A	X73230	0.3

Genes reported to be affected by thyroid hormone are identified using a variety of techniques include microarray analysis. Studies have identified genes that are affected by T3 and T3 mimetics that are important in metabolic diseases.

T3-responsive genes in the liver include genes affecting lipogenesis, including spot 14, fatty acid transport protein, malic enzyme, fatty acid synthase (Blennemann *et al., Mol Cell Endocrinol.* 110(1-2):1-8 (1995)) and CYP4A. HMG CoA reductase and LDL receptor genes have been identified as affecting cholesterol synthesis and as being responsive to T3. CPT-1 is a T3 responsive gene involved in fatty acid oxidation. Genes affecting energy expenditure, including mitochondrial genes such as mitochondrial *sn*-glycerol 3-phosphate dehydrogenase (mGPDH), and/or enzymes associated with proton leakage such as the adenine nucleotide transporter (ANT), Na^+/K^+-ATPase, Ca^{2+}-ATPase and ATP synthase are also T3 responsive genes. T3 responsive genes affecting glycogenolysis and gluconeogenesis, include glucose 6-phosphatase and PEPCK.

Thyroid-responsive genes in the heart are not as well described as the liver but could be determined using similar techniques as described by Feng *et al.* Many of the genes described to be affected in the heart are the same as described above for the liver. Common genes evaluated include mitochondrial *sn*-glycerol 3-phosphate dehydrogenase (mGPDH), and myosin heavy and light chains (Danzi *et al., Thyroid.* 12(6):467-72 (2002)).

Compounds used in the methods bind to thyroid receptors and produce a change in some hepatic gene expression. Evidence for agonist activity is obtained using standard assays described in the literature. One assay commonly used entails a reporter cell assay wherein cells, *e.g.*, HeLa cells, Hek293 cells, chinese ovary cells, are transfected with an expression vector for human TRα1 or TRβ1 and subsequently with a reporter vector encoding a secreted form of alkaline phosphatase containing whose expression is under the control of a thyroid hormone response element. Agonist activity is measured by exposing the cells to the compounds, especially phosphonic acid prodrugs of the compounds that are cleaved to the phosphonic acid by cell homogenates, followed by determining alkaline phosphatase activity in the cell culture medium using a chemiluminescent assay (Grover *et al., Proc. Natl. Acad. Sci. U.S.A.*, 100(17): 10067-72 (2003)).

In one aspect, the phosphonic acid thyromimetics and their prodrugs and salts are useful in preventing or treating arteriosclerosis by modulating levels of atherogenic proteins, *e.g.*, Lp(a), apoAI, apoAII, LDL, HDL. Clinically overt hypothyroidism is associated with accelerated and premature coronary atherosclerosis and subclinical hypothyroidism is considered a condition with an increased risk for these diseases (Vanhaelst *et al.* and Bastenie *et al., Lancet* 2 (1967)).

T3 and T3 mimetics modulate atherogenic proteins in a manner that could prove beneficial for patients at risk to develop atherosclerosis or have patients with atherosclerosis or diseases associated with atherosclerosis. T3 and T3 mimetics are known to decrease Lp(a) levels, *e.g.*, in the monkey with 3,5-dichloro-4-[4-hydroxy-3-(1-methylethyl)phenoxy] benzeneacetic acid (Grover *et al., Proc. Natl. Acad. Sci. U.S.A.*, 100, 10067-10072 (2003)). In human hepatoma cells, the T3 mimetic CGS23425 ([[4-[4-hydroxy-3-(1-methylethyl)phenoxy]-3,5-dimethylphenyl]amino]oxo acetic acid) increased apoAI expression via thyroid hormone receptor activation (Taylor *et al., Mol. Pharm.*, 52, 542-547 (1997)).

Thus in one aspect, the phosphonic acid containing thyromimetics, their salts and prodrugs can be used to treat or prevent atherosclerosis, coronary heart disease and heart failure because such compounds are expected to distribute to the liver (Examples F and H) and modulate the expression and production of atherogenic proteins.

In another aspect, the phosphonic acid containing thyromimetics and their prodrugs and salts are useful for preventing and/or treating metabolic diseases such as obesity, hypercholesterolemia and hyperlipidemia and conditions such as atherosclerosis,

coronary heart disease, heart failure without affecting thyroid function, thyroid production of circulating iodinated thyronines such as T3 and T4, and/or the ratio of T3 to T4. Compounds previously reported that contain a carboxylic acid moiety, *e.g.*, GC-1 ([4-[[4-hydroxy-3-(1-methylethyl)phenyl]methyl]-3,5-dimethylphenoxy] acetic acid)(Trost *et al.*, *Endocrinology*, 141, 3057-3064 (2000)) and 3,5-Dichloro-4-[4-hydroxy-3-(1-methylethyl)phenoxy] benzeneacetic acid (Grover *et al.*, *Proc. Natl. Acad. Sci.* U.S.A., 100, 10067-10072 (2003)) report that these TRβ-selective compounds dose-dependently lower cholesterol and TSH levels. Effects on cholesterol and TSH occur at the same dose or at doses stated to be not pharmacologically different (*e.g.*, 2-fold).

Particularly useful T3 mimetics in these methods would minimize effects on thyroid function, thyroid production of circulating iodinated thyronines such as T3 and T4, and/or the ratio of T3 to T4. Unlike prior T3 mimetics, the compounds or the present invention distribute more readily to the liver and result in pharmacological effects at doses that do not adversely affect thyroid function, thyroid production of circulating iodinated thyronines such as T3 and T4, and/or the ratio of T3 to T4. In one embodiment the compounds of the present invention have a therapeutic index, defined as the difference between the dose at which a significant effect is observed for a use disclosed herein, e.g., lowering cholesterol, and the dose at which a significant decrease in T3 or significant decrease in T4, or significant change in the ratio of T3 to T4 is observed, is at least 50 fold, 100 fold, 200 fold, 300 fold, 400 fold, 500 fold, 600 fold, 700 fold, 800 fold, 900 fold, 1000 fold, 2000 fold, 3000 fold, 4000 fold, 5000 fold, 6000 fold, 7000 fold, 8000 fold, 9000 fold or at least 10000 fold. In one embodiment, rather than a significant amount, the amout of change in T3 or T4 is a decrease selectef from; at least 5%, 10%, 15%, 20%, 25% or at least 30% of circulating levels.

Side effects associated with TH-based therapies limit their use for treating obese patients and according to the Physician's Desk Reference (PDR) T3 is now contraindicated for patients with obesity. 3,5-dichloro-4-[4-hydroxy-3-(1-methylethyl)phenoxy] benzeneacetic acid and other T3 mimetics are reported to result in weight loss in animals, *e.g.*, rodent models and monkeys. Weight loss from these compounds may arise from their effects on the liver as well as peripheral tissues. TH is known to have a multitude of effects outside of the liver that could result in increased metabolism and weight loss. TH plays an important role in the development and function of brown and white adipose tissue. TH can induce WAT differentiation, proliferation and intracellular lipid accumulation. TH induces lipogenic genes in WAT

such as glucose-6-phosphate dehydrogenase, fatty acid synthase and spot-14. TH also regulates lipolysis in fat to produce weight loss in a coordinated manner, *i.e.*, lipolysis in fat to free fatty acids followed by free fatty acid utilization in tissues, *e.g.*, liver, muscle and heart.

Weight loss through administration of liver-specific T3 analogues requires that the increased oxygen consumption in the liver resulting from T3 is sufficient to result in net whole body energy expenditure. The liver's contribution to energy expenditure is estimated to be 22% based on oxygen consumption measurements. (Hsu, A *et al. Am J Clin Nutr.* 77(6):1506-11(2003)). Thus, the compounds of the present invention may be used to maintain or reduce weight in an animal.

Mitochondria are the fuel source for all cellular respiration. The synthesis of new mitochondria is a complex process which requires over 1000 genes (Goffart *et al., Exp Physiol.* Jan. 88(1):33-40 (2003)). The mechanisms which control mitochondrial biogenesis are not well defined, but are known to include exercise (Jones *et al., Am J Physiol Endocrinol Metab.* 2003 Jan. 284(1):E96-101), overexpression of PGC-1 (Lehman *et al., J Clin Invest.* 2000 Oct. 106(7):847-56) or AMP activated protein kinase (Bergeron *et al., Am J Physiol Endocrinol Metab.* 2001 Dec. 281(6):E1340-6). An increase in mitochondrial density leads to a greater rate of energy expenditure. Thyroid hormone has been shown to play a key role in mitochondrial biogenesis by increasing expression of nuclear respiratory factor-1 and PGC-1 (Weitzel *et al., Exp Physiol.* 2003 Jan. 88(1):121-8).

Compounds which increase the expression of NRF-1 and/or PGC-1 could lead to an increase in mitochondrial density within a cell. Such an increase would cause the cell to have a higher rate of energy expenditure. Methods to analyze NRF-1 and PGC-1 include immunoblotting with specific antibodies, or analysis of mRNA levels. Compounds that caused increases in NRF-1 or PGC-1 would therefore lead to a greater energy expenditure. Even small increases in energy expenditure over long periods of time (weeks to years) could cause a decrease in weight under isocaloric circumstances. Further methods for assessing mitochondrial biogenesis include the analysis of mitochondrial proteins such as cytochrome c and cytochrome c oxidase, either by immunoblotting or analysis of mRNA levels. Mitochondrial density can also be measured by counting the number of mitochondria in electron micrographs.

In one aspect, phosphonic acid containing thyromimetics and their prodrugs and salts may be used to cause weight loss or prevent weight gain without side effects. It

may be advantageous to use compounds that result in high liver specificity. (Examples F and G) In one aspect, compounds that result in increased levels of genes associated with oxygen consumption, *e.g.*, GPDH (Example B), are particularly useful in weight loss and controlling weight gain. In another aspect, compounds that show weight loss at doses that do not affect cardiac function, *e.g.*, heart rate, force of systolic contraction, duration of diastolic relaxation, vascular tone, heart weight may be particularly useful in weight loss and controlling weight gain. In a further aspect, compounds that cause weight loss without affecting thyroid function, thyroid production of circulating iodinated thyronines such as T3 and T4, and/or the ratio of T3 to T4 are particularly useful.

Besides their use in obesity and weight control, phosphonic acid containing thyromimetics and their prodrugs and salts may be used to treat diabetes and related conditions like impaired glucose tolerance, insulin resistance and hyperinsulinemia.

Patients with type 2 diabetes "T2DMs" exhibit chronic high blood glucose levels. High fasting blood glucose in T2DMs is related to the overproduction of glucose by a pathway in the liver known as the gluconeogenesis pathway. Throughput in this pathway is controlled in part by enzymes in the pathway such as PEPCK, fructose 1,6-bisphosphatase and glucose 6-phosphatase as well as by hormones such as insulin, which can influence the expression and activities of these enzymes. T3 is known to worsen diabetes. While the reason T3 worsens diabetes is not known, T3's effect on increasing the gene expression of PEPCK and glucose-6-phosphatase may be the cause of increased glucose levels. T3 is known to increase lipolysis of triglyceride pools in fat and to increase circulating levels of free fatty acids. (K.S. Park, *et al., Metabolism* (1999) Oct;48(10):1318-21) T3's effect on free fatty acid levels may also be responsible for the negative effect on diabetes because high free fatty acid levels enhance flux through the gluconeogenesis pathway.

Compounds of this invention, while they mimic T3, result in preferential activation of liver T3 genes, are not expected to increase lipolysis in peripheral tissues which is expected to avoid the T3-induced higher circulating levels of free fatty acids and their effects on increasing gluconeogenesis flux and decreasing insulin sensitivity. Increased hepatic insulin sensitivity will decrease PEPCK and glucose 6-phosphatase gene expression thus reducing gluconeogenesis. TR activation in the liver should also decrease liver fat content, which in turn is expected to improve diabetes and steatohepatitis (*e.g.*, NASH), thrus providing another use for the compounds of the present invention. A decrease in liver fat content is associated with increased hepatic

insulin sensitivity (Shulman, 2000) and accordingly should improve glycemic control in type 2 diabetics through decreased glucose production and enhanced glucose uptake. The overall effect on the patient will be better glycemic control, thus providing another use for the compounds of the present invention.

TH also stimulates GLUT-4 transporter expression in skeletal muscle which produces concomitant increases in basal glucose uptake. Studies in obese, insulin-resistant Zucker rats showed that TH therapy induces GLUT-4 expression in skeletal muscle and total amelioration of the hyperinsulinemia, although plasma glucose levels were moderately elevated (Torrance *et al. Endocrinol.*, 138, 1204 (1997)). Thus another embodiment of the present invention relates to the use of compounds of the present invention to prevent or treat hyperinsulinemia.

TH therapy results in increased energy expenditure. Increased energy expenditure can result in increased weight loss, which in turn can result in improved glycemic control. Diet and exercise are often used initially to treat diabetics. Exercise and weight loss increase insulin sensitivity and improve glycemia. Thus, further uses of the compounds of the present invention include increasing energy expenditure, increasing insuling sensitivity and improving glycemia.

In one aspect, the phosphonic acid containing compounds of the present invention are useful forI increasing levels of genes associated with gluconeogenesis (Example B). In another aspect, the compounds of the present invention are useful for decreasing hepatic glycogen levels. Further, compounds of the present invention result in amelioration of hyperinsulinemia and/or decreased glucose levels in diabetic animal models at doses that do not affect cardiac function, *e.g.*, heart rate, force of systolic contraction, duration of diastolic relaxation, vascular tone, heart weight. In a further aspect, compounds of the present invention result in amelioration of hyperinsulinemia and/or decreased glucose levels in diabetic animal models at doses that do not affect thyroid function, thyroid production of circulating iodinated thyronines such as T3 and T4, and/or the ratio of T3 to T4.

As discussed above, the previous use of T3 and T3 mimetics to treat metabolic diseases have been limited by the deleterious side-effects on the heart. Previous attempts to overcome this limitation have focused on selectively targeting the liver over the heart using T3 mimetics that selectively bind TRβ over TRα. Because the heart expresses mainly TRα, previous investigators have attempted to increase the therapeutic index of

T3 mimetics by increasing the selectively of the compounds for TRβ which is expressed in the liver. Previous attempts have not focused on T3 mimetics that selectively distribute to the liver over the heart or at least have not been successful. Thus, rather than selecting for a particular tissue or organ, previous work has been directed to discovering T3 mimetics that act selectively at the receptor level after the drug is non-selectively distributed to both heart and liver tissue. It was therefore unexpected when the present Inventors discovered that the phosphonic acid compounds of the present invention selectively distributed to the liver over the heart. The selective distribution to the liver over the heart was also found with prodrugs, that although were processed in the liver, were excreted from the liver into the blood stream as active phosphonic acid compounds. Thus the compounds of the present invention are able to selectively target the liver and thereby increase the therapeutic index and compared to T3 and T3 mimetics containing a carboxylic acid. The compounds of the present invention can therefore be dosed at levels that are effective in treating metabolic and other disorders where the liver is the drug target without significantly negatively affecting heart function.

Because of the selectivity of the phosphonic acid containing compounds of the present invention for the liver over the heart, it is not necessary for the compound to have greater selectivity for TRβ over TRα, although this may be desired. In fact, surprisingly some of the compounds of the present invention selectively bind TRα over TRβ and are highly effective for the uses disclosed herein without having the negative side-effects normally associated with TRα selective compounds. Thus, included as an embodiment of the present invention are compounds of Formula I, II and III that selectively bind TRβ over TRα by at least 5 fold, 10 fold, 20 fold, 30 fold, 40 fold, 50 fold, 60 fold, 70 fold, 80 fold, 90 fold, 100 fold, 200 fold, 300 fold, 400 fold or at least 500 fold, and compounds of Formula I, II and III that selectively bind TRα over TRβ by at least 5 fold, 10 fold, 20 fold, 30 fold, 40 fold, 50 fold, 60 fold, 70 fold, 80 fold, 90 fold, 100 fold, 200 fold, 300 fold, 400 fold or at least 500 fold.

Changes in the therapeutic index are readily determined using assays and methods well described in the literature. Genes in extrahepatic tissues are monitored using methods well understood by those skilled in the art. Assays include using cDNA microarray analysis of tissues isolated from treated animals. The sensitivity of the heart to T3 makes analysis of T3-responsive genes in the heart as well as the functional consequences of these changes on cardiac properties one further strategy for evaluating

the therapeutic index of the compounds of the present invention. Cardiac genes measured include mGPDH, myosin heavy and light chain. One method of measuring the effects of T3 mimetics on the heart is by the use of assays that measure T3 mediated myosin heavy chain gene transcription in the heart. Compounds of the present invention were tested using the methods described in Examples B, D, and I.

In one embodiment the compounds of the present invention have a therapeutic index, defined as the difference between the dose at which a significant effect is observed for a use disclosed herein, *e.g.*, lowering cholesterol, and the dose at which a significant effect on a property or function, as disclosed herein (e.g., heart rate), is observed, is at least 50 fold, 100 fold, 200 fold, 300 fold, 400 fold, 500 fold, 600 fold, 700 fold, 800 fold, 900 fold, 1000 fold, 2000 fold, 3000 fold, 4000 fold, 5000 fold, 6000 fold, 7000 fold, 8000 fold, 9000 fold or at least 10000 fold. Examples of said use disclosed herein includes but is not limited to reducing lipid levels, increasing the ratio of HDL to LDL or apoAI to LDL, reducing weight or preventing weight gain, maintaining or improving glycemic control, lowering blood glucose levels, increasing mitochondrial biogenesis, increasing expression of PGC-1, AMP activated protein kinase or nuclear respiratory factor, inhibiting hepatic gluconeogenesis or for the treatment or prevention of of a disease or disorder selected from the group consisting of atherosclerosis, hypercholesterolemia, obesity, NASH, NAFLD, insulin resistance, diabetes, metabolic syndrome X, impaired glucose tolerance, hyperlipidemia, coronary heart disease, thyroid disease, thyroid cancer, depression, glaucoma, cardiac arrhythmias, heart failure, and osteoporosis. Examples wherein the property or function is a cardiac property/function include but is not limted to cardiac hypertrophy (heart weight to body weight ratio), heart rate, and various hemodynamic parameters, including systolic and diastolic arterial pressure, end systolic left ventricular pressure and maximal speeds of contraction and relaxation.

A variety of methods are described that provide a means for evaluating the functional consequences of T3-cardiac action, including measurement of cardiac hypertrophy (heart weight to body weight ratio), heart rate, and various hemodynamic parameters, including systolic and diastolic arterial pressure, end-systolic left ventricular pressure and maximal speeds of contraction and relaxation using methods described by Trost *et al.*, (*Endocrinol.*, 141: 3057-64 (2000)). Compounds of the present invention were tested using the methods described in Examples B, D, and I.

Other methods are also available to assess the therapeutic index including effects on muscle wasting and bone density. Compounds of the present invention were tested using the methods described in Examples C and G.

The therapeutic index is determined by administering to animals a wide range of doses and determining the minimal dose capable of inducing a response in the liver relative to the dose capable of inducing a response in the heart.

Phosphonic acids are often poorly transported into cultured cells. Accordingly, cell reporter assays, while often useful for confirming agonist activity, may not provide a suitable indication of potency. Thus, evidence of agonist activity is often more readily obtained *in vivo* for compounds of the present invention. *In vivo* assays include but are not limited to treating animals with phosphonic acids of the invention or a phosphonic acid prodrug and monitoring the expression of T3-responsive genes in the liver or the functional consequences of changes of T3-responsive genes.

In one aspect, compounds useful in the novel methods bind to thyroid receptors and produce changes in the expression of two or more hepatic genes. Animals used for testing compounds useful in the methods include normal rats and mice, animals made hypothyroid using methods well described in the literature, including thyroid hormone receptor knockout mice (*e.g.*, $TR\alpha^{-/-}$ such as those used in Grover *et al.*, 2003), or animals exhibiting high cholesterol (*e.g.*, high cholesterol fed rat or hamster), obesity and/or diabetes (*e.g.*, *fa/fa* rat, Zucker diabetic fatty rat, *ob/ob* mice, *db/db* mice, high fat fed rodent). (Liureau *et al.*, *Biochem Pharmacol.* 35(10):1691-6 (1986); Trost *et al.*, *Endocrinology* 141(9):3057-64 (2000); and Grover, *PNAS* 2003). The drug or prodrug is administered by a variety of routes including by bolus injection, oral, and continuous infusion (Examples B, D and I). Animals are treated for 1-28 days and the liver, heart and blood are isolated. Changes in gene transcription relative to vehicle treated animals and T3-treated animals are determined using northern blot analysis, RNAase protection or reverse-transcription and subsequent PCR. While methods are available for monitoring changes in thousands of hepatic genes, only a small number need to be monitored to demonstrate the biological effect of compounds in this invention. Typically, genes such as spot-14, FAS, mGPDH, CPT-1, and LDL receptor are monitored. Changes of >1.5 fold in two or more genes is considered proof that the compound modulates T3-responsive genes *in vivo*. Alternative methods for measuring changes in gene transcription include monitoring the activity or expression level of the protein encoded by the gene. For instance, in cases where the genes encode enzyme

activities (*e.g.*, FAS, mGPDH), direct measurements of enzyme activity in appropriately extracted liver tissue can be made using standard enzymological techniques. In cases where the genes encode receptor functions (*e.g.*, the LDL receptor) ligand binding studies or antibody-based assays (*e.g.*,Westerns) can be performed to quantify the number of receptors expressed. Depending on the gene, TR agonists will either increase or decrease enzyme activity or increase or decrease receptor binding or number.

The functional consequences of changing the expression levels of hepatic genes responsive to T3 is many-fold and readily demonstrated using assays well described in the literature. Administering phosphonic acid containing compounds that bind to a TR to animals can result in changes in lipids, including hepatic and/or plasma cholesterol levels; changes in lipoprotein levels including LDL-cholesterol, lipoprotein a (Lp(a)); changes in hepatic glycogen levels; and changes in energy expenditure as measured by changes in oxygen consumption and in some cases animal weight. For example, the effect on cholesterol is determined using cholesterol fed animals such as normal rats and hamsters, or $TR\alpha^{-/-}$ knockout mice. Cholesterol is measured using standard tests. Compounds of the present invention were tested using the methods described in Example D and I. Hepatic glycogen levels are determined from livers isolated from treated animals. Compounds of the present invention were tested using the methods described in Examples D and E. Changes in energy expenditure are monitored by measuring changes in oxygen consumption (MVo_2). A variety of methods are well described in the literature and include measurement in the whole animal using Oxymax chambers (US6441015). Livers from treated rats can also be evaluated (Fernandez *et al.*, *Toxicol Lett.* 69(2):205-10 (1993)) as well as isolated mitochondria from liver (Carreras, *et al.*, *Am J Physiol Heart Circ Physiol.* 281(6):H2282-8 (2001)). Hepatocytes from treated rats can also be evaluated (Ismail-Beigi F *et al.*, *J Gen Physiol.* 73(3):369-83 (1979)). Compounds of the present invention are tested using the methods described in Examples C and G.

Phosphonic acid containing compounds that bind to a TR modulate expression of certain genes in the liver resulting in effects on lipids (*e.g.*, cholesterol), glucose, lipoproteins, and triglycerides. Such compounds can lower cholesterol levels which is useful in the treatment of patients with hypercholesterolemia. Such compounds can lower levels of lipoproteins such as Lp(a) or LDL and are useful in preventing or treating patients with atherosclerosis and heart disease. Such compounds can raise levels of

lipoproteins such as apoAI or HDL and are useful in preventing or treating patients with atherosclerosis and heart disease. Such compounds can cause a reduction in weight. Such compounds can lower glucose levels in patients with diabetes.

Another aspect are compounds that in the presence of liver cells or microsomes results in compounds of Formula I, II and III wherein X is $-P(O)(OH)_2$.

Also provided are methods of reducing plasma lipid levels in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter enantiomerically enriched disastereomeric enriched, or a stereoisomer covered later. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of reducing plasma lipid levels in an animal wherein the lipid is cholesterol, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer. In one embodiment said methods of reducing cholesterol results in a lowering of total cholesterol. In one embodiment said methods of reducing cholesterol results in a reduction of high density lipoprotein (HDL). In one embodiment said methods of reducing cholesterol results in a reduction of low density lipoprotein (LDL). In one embodiment said methods of reducing cholesterol results in a reduction of very low density lipoprotein (VLDL). In another embodiment said LDL is reduced to a greater extent than said HDL. In another embodiment said VLDL is reduced to a greater

extent than said HDL. In another embodiment said VLDL is reduced to a greater extent than said LDL.

In one embodiment of the method of reducing lipids, lipid is triglycerides. In one embodiment said lipid is liver triglycerides. In another embodiment said lipid is in the form of a lipoprotein. In another embodiment said lipoprotein is Lp(a). In another embodiment said lipoprotein is apoAII.

Also provided are methods of increasing the ratio of HDL to LDL, HDL to VLDL, LDL to VLDL, apoAI to LDL or apoAI to VLDL in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III or VIII a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of treating hypercholesterolemia in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of preventing or treating atherosclerosis in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment

said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of reducing fat content in the liver or of preventing or treating steatosis, NASH or NAFLD in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of reducing weight or preventing weight gain in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of preventing or treating obesity in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of preventing or treating coronary heart disease in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of maintaining or improving glycemic control in an animal being treated with a T3 mimetic, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer. In one embodiment said glycemic control is maintained after said animal is treated for at least 14 days with said compound. In another embodiment said glycemic control is improved by 28 days in an animal treated with said compound.

Also provided are methods of lowering blood glucose levels in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of preventing or treating diabetes, insulin resistence, metabolic syndrome X or impaired glucose tolerance in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of preventing or treating altered energy expenditure in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of preventing or treating a liver disease responsive to modulation of T3-responsive genes in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of preventing or treating thyroid disease, thyroid cancer, depression, glaucoma, cardiac arrhythmias, heart failure, or osteoporosis in an

animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII,or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of increasing mitochondrial biogenesis in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of increasing expression of PGC-1, AMP activated protein kinase or nuclear respiratory factor in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are methods of inhibiting hepatic gluconeogenesis in an animal, the method comprising the step of administering to a patient an amount of a compound of Formula I, II, III, or VIII, a prodrug thereof, or a pharmaceutically acceptable salt or co-crystal thereof. In one embodiment said compound is an active form. In another

embodiment said compound is a prodrug. In another embodiment said compound of Formula I, II, III, or VIII or a prodrug thereof comprises a stereocenter. In another embodiment said compound is admistered as a racemic mixture. In another embodiment said compound is admistered as an enantiomerically enriched mixture. In another embodiment said compound is a admistered as a diasteromeric mixture. In still another embodiment said compound is admistered as an individual stereoisomer.

Also provided are kits for reducing lipid levels, increasing the ratio of HDL to LDL or apoAI to LDL, reducing weight or preventing weight gain, maintaining or improving glycemic control, lowering blood glucose levels, increasing mitochondrial biogenesis, increasing expression of PGC-1, AMP activated protein kinase or nuclear respiratory factor, inhibiting hepatic gluconeogenesis, or for the prevention or treatment of a disease or disorder for which a compound of the present invention is effective in preventing or treating, the kits comprising:

a) a pharmaceutical composition comprising a compound of Formula I, II, III, or VIII or a prodrug thereof; and

b) at least one container for containing said pharmaceutical composition.

Also provided are pharmaceutical compositions comprising a compound of Formula I and a pharmaceutically acceptable excipient, carrier or diluent. Also provided are pharmaceutical compositions comprising a first pharmaceutical compound selected from Formula I, Formula II or Formula III or Formula VIII or a prodrug thereof and a second pharmaceutical compound of the same Formula but wherein said first and second pharmaceutical compounds are not the same molecules. Also provided are pharmaceutical compositions comprising a first pharmaceutical compound selected from Formula I, Formula II or Formula III or Formula VIII or a prodrug thereof and a second pharmaceutical compound selected from Formula I, Formula II, Formula III, or Formula VIII or a prodrug thereof, but wherein said first and said second pharmaceutical compounds are not both from the same Formula. Also provided are pharmaceutical compositions comprising a first pharmaceutical compound selected from Formula I, Formula II, Formula III, or Formula VIII or a prodrug thereof and a second pharmaceutical compound that is not a compound selected from Formula I, Formula II, Formula III, or Formula VIII or a prodrug thereof.

Also provided are pharmaceutical compositions comprising a first compound of present invention and a second compound useful for reducing lipid levels, increasing the ratio of HDL to LDL or apoAI to LDL, reducing weight or preventing weight gain,

maintaining or improving glycemic control, lowering blood glucose levels, increasing mitochondrial biogenesis, increasing expression of PGC-1, AMP activated protein kinase or nuclear respiratory factor, inhibiting hepatic gluconeogenesis or for the treatment or prevention of atherosclerosis, hypercholesterolemia, obesity, steatosis, NASH, NAFLD, insulin resistance, diabetes, metabolic syndrome X, impaired glucose tolerance, hyperlipidemia, coronary heart disease, thyroid disease, thyroid cancer, depression, glaucoma, cardiac arrhythmias, heart failure, or osteoporosis. In one embodiment, and composition comprising said first and second compound is a single unit dose. In another embodiment, said unit does is in the form of a tablet, hard capsule or soft gel capsule.

Also provided are pharmaceutical compositions of the present invention having an oral bioavailability of least 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70% 75% or at least 80%.

Also provided are kits for the prevention or treatment of a disease or disorder for which a compound of the present invention is effective in preventing or treating, the kits comprising:

a) a first pharmaceutical composition comprising a compound of I, II, III, or VIII or a prodrug thereof ;

b) a second pharmaceutical composition comprising an additional compound useful for the treatment or prevention of a disease or disorder for which a compound of the present invention is effective in preventing or treating; and

c) at least one container for containing said first or second or both first and second pharmaceutical composition.

Also provided are kits for reducing lipid levels, increasing the ratio of HDL to LDL or apoAI to LDL, reducing weight or preventing weight gain, maintaining or improving glycemic control, lowering blood glucose levels, increasing mitochondrial biogenesis, increasing expression of PGC-1, AMP activated protein kinase or nuclear respiratory factor, inhibiting hepatic gluconeogenesis or for the treatment or prevention of of a disease or disorder selected from the group consisting of atherosclerosis, hypercholesterolemia, obesity, steatosis, NASH, NAFLD, insulin resistance, diabetes, metabolic syndrome X, impaired glucose tolerance, hyperlipidemia, coronary heart disease, thyroid disease, thyroid cancer, depression, glaucoma, cardiac arrhythmias, heart failure, and osteoporosis, the kits comprising:

a) a first pharmaceutical composition comprising a compound of Formula I, II, III, or VIII or a prodrug thereof;

b) a second pharmaceutical composition comprising an additional compound useful for reducing lipid levels, increasing the ratio of HDL to LDL or apoAI to LDL, reducing weight or preventing weight gain, maintaining or improving glycemic control, lowering blood glucose levels, increasing mitochondrial biogenesis, increasing expression of PGC-1, AMP activated protein kinase or nuclear respiratory factor, inhibiting hepatic gluconeogenesis or for the treatment or prevention of atherosclerosis, hypercholesterolemia, obesity, steatosis, NASH, NAFLD, insulin resistance, diabetes, metabolic syndrome X, impaired glucose tolerance, hyperlipidemia, coronary heart disease, thyroid disease, thyroid cancer, depression, glaucoma, cardiac arrhythmias, heart failure, or osteoporosis; and

c) at least one container for containing said first or second or both first and second pharmaceutical composition.

Also provided are methods for reducing lipid levels, increasing the ratio of HDL to LDL or apoAI to LDL, reducing weight or preventing weight gain, maintaining or improving glycemic control, lowering blood glucose levels, increasing mitochondrial biogenesis, increasing expression of PGC-1, AMP activated protein kinase or nuclear respiratory factor, inhibiting hepatic gluconeogenesis or for the treatment or prevention of atherosclerosis, hypercholesterolemia, obesity, NASH, NAFLD, insulin resistance, diabetes, metabolic syndrome X, impaired glucose tolerance, hyperlipidemia, coronary heart disease, thyroid disease, thyroid cancer, depression, glaucoma, cardiac arrhythmias, heart failure, or osteoporosis the methods comprising the step of administering to a patient a therapeutically effective amount of 1) a first pharmaceutical composition comprising a compound of Formula I, II, III, or VIII or a prodrug thereof, and 2) a second pharmaceutical composition, wherein said second pharmaceutical composition is either another compound of Formula I, II, III, or VIII or a prodrug thereof, or is not another compound of Formula I, II, III, or VIII or a prodrug thereof.

Also provided are methods for reducing lipid levels, increasing the ratio of HDL to LDL or apoAI to LDL, reducing weight or preventing weight gain, maintaining or improving glycemic control, lowering blood glucose levels, increasing mitochondrial biogenesis, increasing expression of PGC-1, AMP activated protein kinase or nuclear respiratory factor, inhibiting hepatic gluconeogenesis or for the treatment or prevention of atherosclerosis, hypercholesterolemia, obesity, NASH, NAFLD, insulin resistance, diabetes, metabolic syndrome X, impaired glucose tolerance, hyperlipidemia, coronary heart disease, thyroid disease, thyroid cancer, depression, glaucoma, cardiac arrhythmias,

heart failure, or osteoporosis the methods comprising the step of administering to a patient a therapeutically effective amount of 1) a first pharmaceutical composition comprising a compound of Formula I, II, III, or VIII or a prodrug thereof and 2) an second pharmaceutical composition that is effective alone for reducing lipid levels, increasing the ratio of HDL to LDL or apoAI to LDL, reducing weight or preventing weight gain, maintaining or improving glycemic control, lowering blood glucose levels, increasing mitochondrial biogenesis, increasing expression of PGC-1, AMP activated protein kinase or nuclear respiratory factor, inhibiting hepatic gluconeogenesis or for the treatment or prevention of atherosclerosis, hypercholesterolemia, obesity, NASH, NAFLD, insulin resistance, diabetes, metabolic syndrome X, impaired glucose tolerance, hyperlipidemia, coronary heart disease, thyroid disease, thyroid cancer, depression, glaucoma, cardiac arrhythmias, heart failure, or osteoporosis.

Also provided is the use of a compound of the present invention for the manufacture of a medicament for reducing lipid levels, increasing the ratio of HDL to LDL or apoAI to LDL, reducing weight or preventing weight gain, maintaining or improving glycemic control, lowering blood glucose levels, increasing mitochondrial biogenesis, increasing expression of PGC-1, AMP activated protein kinase or nuclear respiratory factor, inhibiting hepatic gluconeogenesis or for the treatment or prevention of atherosclerosis, hypercholesterolemia, obesity, NASH, NAFLD, insulin resistance, diabetes, metabolic syndrome X, impaired glucose tolerance, hyperlipidemia, coronary heart disease, thyroid disease, thyroid cancer, depression, glaucoma, cardiac arrhythmias, heart failure, or osteoporosis.

Also provided are compounds that selectively distribute to the liver. In one embodiment, the compounds have at least 10 fold, 25 fold, 50 fold, 75 fold, 100 fold, 200 fold, 300 fold, 400 fold, 500 fold, 600 fold, 700 fold, 800 fold, 900 fold, 1000 fold, 2000 fold, 3000 fold, 4000 fold, 5000 fold 6000 fold, 7000 fold, 8000 fold, 9000 fold, 10,000 fold, 20,000 fold, 30,000 fold, 40,000 fold or 50,000 fold greater selectivity. In one embodiment the selectivity for the liver is compared to the heart. In another embodiment the selectivity for the liver is compared to the pituitary. In another embodiment the selectivity for the liver is compared to the kidney.

Also provided are T3 mimetics comprising a phosphonic acid or prodrug thereof that have improved liver selectivity as compared to a corresponding compound where the phosphonic acid is replaced with a carboxylic acid, but wherein the corresponding compound is otherwise identical. In one embodiment, the phosphonic acid (or prodrug

thereof) compound has at least 10 fold, 25 fold, 50 fold, 75 fold, 100 fold, 200 fold, 300 fold, 400 fold, 500 fold, 600 fold, 700 fold, 800 fold, 900 fold, 1000 fold, 2000 fold, 3000 fold, 4000 fold, 5000 fold 6000 fold, 7000 fold, 8000 fold, 9000 fold, 10,000 fold, 20,000 fold, 30,000 fold, 40,000 fold or 50,000 fold greater selectivity for the liver as compared to the corresponding carboxylic acid compound. In one embodiment the liver selectivity is relative to the heart. In another embodiment the liver selectivity is relative to the kidney. In another embodiment the liver selectivity is relative to the pituitary.

Also provided are T3 mimetics comprising a phosphonic acid or producing thereof and that have a decreased Ki as compared to a corresponding compound where the phosphonic acid is replaced with a carboxylic acid, but wherein the corresponding compound is otherwise identical. In one embodiment, the phosphonic acid compound has at least 2 fold, 5 fold, 7 fold, 10 fold, 25 fold, or 50 fold lower Ki than the corresponding carboxylic acid derivative compound (wherein Ki is measured relative to T3). In another embodiment, the Ki of the phosphonic acid compound is ≤ 150 nM ≤ 100 nM, ≤ 90nM, ≤ 80nM, ≤ 70nM, ≤ 60nM, ≤ 50nM, ≤ 40nM, ≤ 30nM, relative to T3. For purposes of clarity, it is noted that binding affinity increases as the numerical value of Ki decreases, *i.e.*, there is an inverse relationship between Ki and binding affinity. In another embodiment the phosphonic acid compound has the same Ki as the corresponding carboxylic acid derivative. In another embodiment the phosphonic acid compound has a greater Ki than the corresponding carboxylic acid derivative.

Also provided are compounds of the present invention that bind at least one thyroid hormone receptor with an Ki of ≤ 100 nM, ≤ 90nM, ≤ 80nM, ≤ 70nM, ≤ 60nM, ≤ 50nM, ≤ 40nM, ≤ 30nM, ≤ 20nM, ≤ 10nM, ≤ 50nM, ≤1nM, or ≤ 0.5 nM relative to T3. In one embodiment said thyroid hormone receptor is TRα. In one embodiment said thyroid hormone receptor is TRβ. Also provided are compounds that bind at least one thyroid hormone receptor with an Ki of ≥ 100 nM, ≥ 90nM, ≥ 80nM, ≥ 70nM, ≥ 60nM, ≥ 50nM, ≥ 40nM, ≥ 30nM, ≥ 20nM, ≥ 10nM, ≥ 50nM, ≥1nM, or ≥ 0.5 nM relative to T3, but in each case ≤ 150nM. In one embodiment said thyroid hormone receptor is TRα. In one embodiment said thyroid hormone receptor is TRβ. In one embodiment said thyroid hormone receptor is TRα1. In one embodiment said thyroid hormone receptor is TRβ1. In one embodiment said thyroid hormone receptor is TRα2. In one embodiment said thyroid hormone receptor is TRβ2.

Novel methods described herein describe the use of phosphonic acid-containing compounds that bind to TRs. In one aspect, novel compounds described below include compounds of Formula I, II, III or VIII. The compounds of the persent invention can be used in the methods described herein.

NOVEL COMPOUNDS OF THE INVENTION

The novel compounds of the invention are phosphonic acid containing compounds that bind to and activate thyroid receptors in the liver. The present invention relates to compounds of Formula I, II, III, and VIII, including stereoisomers and mixtures of stereoisomers thereof, pharmaceutically acceptable salts thereof, co-crystals thereof, and prodrugs (including sterioisomers and mixtures of stereoisomers thereof) thereof, and pharmaceutically acceptable salts and co-crystals of the prodrugs.

The compounds of the present invention may be either crystalline, amorphous or a mixture thereof. Compositions comprising a crystalline form a compound of the present invention may contain only one crystalline form of said compound or more than one crystalline form. For example, the composition may contain two or more different polymorphs. The polymorphs may be two different polymorphs of the free form, two or more polymorphs of different co-crystal forms, two or more polymorphs of different salt forms, a combination of one or more polymorphs of one or more co-crystal forms and one or more polymorphs of the free form, a combination of one or more polymorphs of one or more salt forms and one or more polymorphs of the free form, or a combination of one or more polymorphs of one or more co-crystal forms and one or more polymorphs of one or more salt forms.

Pharmaceutically acceptable base addition salt of the compounds herein are included in the present invention. Pharmaceutically acceptable base addition salt refers to those salts which retain the biological effectiveness and properties of the free acids, which are not biologically or otherwise undesirable. These salts are prepared from addition of an inorganic base or an organic base to the free acid. Salts derived from inorganic bases include, but are not limited to: sodium, potassium, lithium, ammonium, calcium, magnesium, zinc, aluminum salts and the like. Preferred inorganic salts are the ammonium, sodium, potassium, calcium, and magnesium salts. Salts derived from organic bases include, but are not limited to, salts of primary, secondary, and tertiary amines, substituted amines including naturally occurring substituted amines, cyclic amines and basic ion exchange resins, such as isopropylamine, trimethylamine,

diethylamine, triethylamine, tripropylamine, ethanolamine, 2-dimethylaminoethanol, 2-diethylaminoethanol, trimethamine, dicyclohexylamine, lysine, arginine, histidine, caffeine, procaine, hydrabamine, choline, betaine, ethylenediamine, glucosamine, methylglucamine, theobromine, purines, piperazine, piperidine, N-ethylpiperidine, polyamine resins and the like.

Pharmaceutically acceptable acid addition salt of the compounds herein having a base functional group (*e.g.*, a prodrug whereby the phosphonic acid is protected with a group comprising a base functional group) are also included in the present invention. Pharmaceutically acceptable acid addition salt refers to those salts which retain the biological effectiveness and properties of the free base, which are not biologically or otherwise undesirable. These salts are prepared from addition of an inorganic acid or an organic acid to the free base. Salts derived from inorganic acids include, but are not limited to: acistrate, hydrobromide, hydrochloride, sulfate, bisulfate, nitrate, acetate, oxalate, besylate, palmitate, stearate, laurate, borate, benzoate, lactate, phosphate, tosylate, citrate, maleate, fumarate, succinate, tartrate, naphthylate, mesylate, glucoheptonate, lactobionate, laurylsulphonate. bromide, fumarate, pamoate, glucouronate, hydroiodide, iodide, sulfate, xinofoate and chloride salts

The compounds of the present invention may be pure or substansially pure or have a purity of at least 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or purity at least 99.5%. The compounds may also be part of the pharmaceutically acceptable composition. The compounds may also be part of a biological material or sample. Thus, included in the present invention are cells and tissues comprising a compound of the present invention. The cells or tissues can be in vivo, ex vivo or in vitro. Examples include liver or liver cells (*e.g.*, hepatocytes), blood, gastric fluid (simulated or actual), intestional fluid (simulated or actual) and urine.

In one aspect the invention relates to a phosphonic acid-containing-thyromimetic compound of Formula X:

$$(Ar^1)\text{-}G\text{-}(Ar^2)\text{-}T\text{-}X$$

wherein:

Ar^1 and Ar^2 are aryl groups;

G is an atom or group of atoms that links Ar^1 and Ar^2 are aryl groups; through a single C, S, O, or N atom;

T is an atom or group of atoms linking Ar^2 to X through 1-4 contiguous atoms or is absent;

X is a $-P(O)(OH)_2$ or prodrug thereof. In one embodiment the compound has a Ki $\leq$ 150nM. Another embodiment included a pharmaceutical composition comprising the compound and a at least one excipient. In another embodiment the pharmaceutical composition has a bioavailability of at least 15%. In another embodiment the compound is crystalline. In another embodiment the pharmaceutical composition is a unit dose. In one embodiment, when the compound of Formula X is a compound of Formula I wherein G is -O-, T is $-CH_2-$, R^1 and R^2 are each bromo, R^3 is *iso*-propyl, R^4 is hydrogen, and R^5 is –OH, then X is not $P(O)(OH)_2$ or $P(O)(OCH_2CH_3)_2$. In another embodiment, when the compound of Formula X is a compound of Formula I wherein G is -O-, T is $-(CH_2)_{0-4}-$, R^1 and R^2 are independently halogen, alkyl of 1 to 3 carbons, and cycloalkyl of 3 to 5 carbons, R^3 is alkyl of 1 to 4 carbons or cycloalkyl of 3 to 7 carbons, R^4 is hydrogen, and R^5 is -OH, then X is not $-P(O)(OH)_2$ or -P(O)(O-lower alkyl)$_2$. In another embodiment, when the compound of Formula X is a compound of Formula I wherein G is -O-, R^5 is $-NHC(O)R^e$, $-NHS(=O)_{1-2}R^e$, $-NHC(S)NH(R^h)$, or $-NHC(O)NH(R^h)$, T is $-(CH_2)_m-$, -CH=CH-, $-O(CH_2)_{1-2}-$, or $-NH(CH_2)_{1-2}-$, then X is not $-P(O)(OH)_2$ or $-P(O)(OH)NH_2$. In another embodiment, when the compound of Formula X is a compound of Formula III wherein G is -O-, T is $-NH-CH_2-$, R^1 and R^2 are each chloro, R^3 is *iso*-propyl, R^4 is hydrogen, R^7 is fluoro, and R^5 is –OH, then X is not $P(O)(OH)_2$, $P(O)(OH)(OCH_3)$ or $P(O)(OCH_3)_2$. In another embodiment, when the compound of Formula X is a compound of Formula III wherein G is selected from the group consisting of -O-, -S-, -S(=O)-, $-S(=O)_2-$, $-CH_2-$, -C(O)- and $-NR^b-$; T is –A-B- where A is selected from the group consisting of $-NR^b-$, -O-, $-CH_2-$ and –S- and B is selected from the group consisting of a bond and substituted or unsubstituted C_1-C_3 alkyl; R^3 is selected from the group consisting of halogen, trifluoromethyl, substituted or unsubstituted C_1-C_6 alkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl, aryloxy, substituted amide, sulfone, sulfonamide and C_3-C_7 cycloalkyl, wherein said aryl, heteroaryl or cycloalkyl ring(s) are attached or fused to the aromatic; R^4 is selected from the group consisting of hydrogen, halogen, substituted or unsubstituted C_1-C_6 alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; R^1 and R^2 are each independently selected from the group consisting of halogen, substituted or unsubstituted C_1-C_4 alkyl, and substituted or unsubstituted C_3-C_5 cycloalkyl; R^7 is selected selected from the group consisting of hydrogen, halogen, amino, hydroxyl, -O-C_1-C_4 alkyl, -SH and -S-C_1-C_4 alkyl; and R^5 is

selected from the group consisting of hydroxyl, optionally substituted $-OC_1-C_6$ alkyl, and $-OC(O)R^e$; then X is not $-P(O)(OH)_2$.

In another aspect the invention relates to a method of improving liver versus heart selectivity or for increasing the therapeutic index of a thyromimetic compound of Formula Y:

$$(Ar^1)\text{-}G\text{-}(Ar^2)\text{-}T\text{-}E$$

wherein:

Ar^1 and Ar^2 are aryl groups;

G is an atom or group of atoms that links Ar^1 and Ar^2 are aryl groups; through a single C, S, O, or N atom;

T is an atom or group of atoms linking Ar^2 to E through 1-4 contiguous atoms or is absent;

E is a functional group or moiety with a $pKa \leq 7.4$, is carboxylic acid (COOH) or esters thereof, sulfonic acid, tetrazole, hydroxamic acid, 6-azauracil, thiazolidinedione, acylsulfonamide, or other carboxylic acid surrogates known in the art or a prodrug thereof, or an atom or group of atoms containing an O or N that binds the thyroid hormone binding pocket of a TRα or TRβ, but wherein E is not a $-P(O)(OH)_2$ or ester thereof; comprising the step of replacing E with a $-P(O)(OH)_2$ or prodrug thereof. In one embodiment the compound has a $Ki \leq 150nM$. Another embodiment included a pharmaceutical composition comprising the compound and a at least one excipient. In another embodiment the pharmaceutical composition has a bioavailability of at least 15%. In another embodiment the compound is crystalline. In another embodiment the pharmaceutical composition is a unit dose. In one embodiment, when the compound of Formula X is a compound of Formula I wherein G is -O-, T is $-CH_2-$, R^1 and R^2 are each bromo, R^3 is *iso*-propyl, R^4 is hydrogen, and R^5 is –OH, then X is not $P(O)(OH)_2$ or $P(O)(OCH_2CH_3)_2$. In another embodiment, when the compound of Formula X is a compound of Formula I wherein G is -O-, T is $-(CH_2)_{0-4}-$, R^1 and R^2 are independently halogen, alkyl of 1 to 3 carbons, and cycloalkyl of 3 to 5 carbons, R^3 is alkyl of 1 to 4 carbons or cycloalkyl of 3 to 7 carbons, R^4 is hydrogen, and R^5 is -OH, then X is not $-P(O)(OH)_2$ or -P(O)(O-lower alkyl)$_2$. In another embodiment, when the compound of Formula X is a compound of Formula I wherein G is -O-, R^5 is $-NHC(O)R^e$, $-NHS(=O)_{1-2}R^e$, $-NHC(S)NH(R^h)$, or $-NHC(O)NH(R^h)$, T is $-(CH_2)_m-$, -CH=CH-, $-O(CH_2)_{1-2}-$, or $-NH(CH_2)_{1-2}-$, then X is not $-P(O)(OH)_2$

or $-P(O)(OH)NH_2$. In another embodiment, when the compound of Formula X is a compound of Formula III wherein G is -O-, T is $-NH-CH_2-$, R^1 and R^2 are each chloro, R^3 is *iso*-propyl, R^4 is hydrogen, R^7 is fluoro, and R^5 is –OH, then X is not $P(O)(OH)_2$, $P(O)(OH)(OCH_3)$ or $P(O)(OCH_3)_2$. In another embodiment, when the compound of Formula X is a compound of Formula III wherein G is selected from the group consisting of -O-, -S-, -S(=O)-, $-S(=O)_2-$, $-CH_2-$, -C(O)- and $-NR^b-$; T is –A-B- where A is selected from the group consisting of $-NR^b-$, -O-, $-CH_2-$ and –S- and B is selected from the group consisting of a bond and substituted or unsubstituted C_1-C_3 alkyl; R^3 is selected from the group consisting of halogen, trifluoromethyl, substituted or unsubstituted C_1-C_6 alkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl, aryloxy, substituted amide, sulfone, sulfonamide and C_3-C_7 cycloalkyl, wherein said aryl, heteroaryl or cycloalkyl ring(s) are attached or fused to the aromatic; R^4 is selected from the group consisting of hydrogen, halogen, substituted or unsubstituted C_1-C_6 alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; R^1 and R^2 are each independently selected from the group consisting of halogen, substituted or unsubstituted C_1-C_4 alkyl, and substituted or unsubstituted C_3-C_5 cycloalkyl; R^7 is selected selected from the group consisting of hydrogen, halogen, amino, hydroxyl, -O-C_1-C_4 alkyl, -SH and -S-C_1-C_4 alkyl; and R^5 is selected from the group consisting of hydroxyl, optionally substituted -OC_1-C_6 alkyl, and $-OC(O)R^e$; then X is not $-P(O)(OH)_2$.

In another aspect the invention relates to a method of designing a thyromimetic compound with improved liver versus heart selectivity or improved therapeutic index comprising the steps of:

obtaining a formula for a thyromimetic of Formula Y:

$$(Ar^1)\text{-}G\text{-}(Ar^2)\text{-}T\text{-}E$$

wherein:

Ar^1 and Ar^2 are aryl groups;

G is an atom or group of atoms that links Ar^1 and Ar^2 are aryl groups; through a single C, S, O, or N atom;

T is an atom or group of atoms linking Ar^2 to E through 1-4 contiguous atoms or is absent;

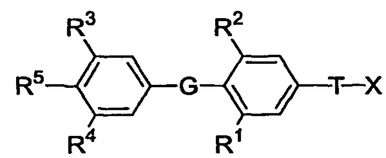
E is a functional group or moiety with a pKa $\leq$ 7.4, is carboxylic acid (COOH) or esters thereof, sulfonic acid, tetrazole, hydroxamic acid, 6-azauracil, thiazolidinedione, acylsulfonamide, or other carboxylic acid surrogates known in the art or a prodrug

thereof, or an atom or group of atoms containing an O or N that binds the thyroid hormone binding pocket of a TRα or TRβ, but wherein E is not a $-P(O)(OH)_2$ or ester thereof; comprising the step of replacing E with a $-P(O)(OH)_2$ or prodrug thereof; and synthesizing a compound of Formula X wherein X is phosphonic acid or prodrug thereof. In one embodiment the compound has a Ki ≤ 150nM. Another embodiment included a pharmaceutical composition comprising the compound and a at least one excipient. In another embodiment the pharmaceutical composition has a bioavailability of at least 15%. In another embodiment the compound is crystalline. In another embodiment the pharmaceutical composition is a unit dose. In one embodiment, when the compound of Formula X is a compound of Formula I wherein G is -O-, T is $-CH_2-$, R^1 and R^2 are each bromo, R^3 is *iso*-propyl, R^4 is hydrogen, and R^5 is –OH, then X is not $P(O)(OH)_2$ or $P(O)(OCH_2CH_3)_2$. In another embodiment, when the compound of Formula X is a compound of Formula I wherein G is -O-, T is $-(CH_2)_{0-4}-$, R^1 and R^2 are independently halogen, alkyl of 1 to 3 carbons, and cycloalkyl of 3 to 5 carbons, R^3 is alkyl of 1 to 4 carbons or cycloalkyl of 3 to 7 carbons, R^4 is hydrogen, and R^5 is -OH, then X is not $-P(O)(OH)_2$ or -P(O)(O-lower alkyl)$_2$. In another embodiment, when the compound of Formula X is a compound of Formula I wherein G is -O-, R^5 is $-NHC(O)R^e$, $-NHS(=O)_{1-2}R^e$, $-NHC(S)NH(R^h)$, or $-NHC(O)NH(R^h)$, T is $-(CH_2)_m-$, -CH=CH-, $-O(CH_2)_{1-2}-$, or $-NH(CH_2)_{1-2}-$, then X is not $-P(O)(OH)_2$ or $-P(O)(OH)NH_2$. In another embodiment, when the compound of Formula X is a compound of Formula III wherein G is -O-, T is $-NH-CH_2-$, R^1 and R^2 are each chloro, R^3 is *iso*-propyl, R^4 is hydrogen, R^7 is fluoro, and R^5 is –OH, then X is not $P(O)(OH)_2$, $P(O)(OH)(OCH_3)$ or $P(O)(OCH_3)_2$. In another embodiment, when the compound of

Formula X is a compound of Formula III wherein G is selected from the group consisting of -O-, -S-, -S(=O)-, $-S(=O)_2-$, $-CH_2-$, -C(O)- and $–NR^b–$; T is –A-B- where A is selected from the group consisting of $–NR^b–$, -O-, $-CH_2-$ and –S- and B is selected from the group consisting of a bond and substituted or unsubstituted C_1-C_3 alkyl; R^3 is selected from the group consisting of halogen, trifluoromethyl, substituted or unsubstituted C_1-C_6 alkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl, aryloxy, substituted amide, sulfone, sulfonamide and C_3-C_7 cycloalkyl, wherein said aryl, heteroaryl or cycloalkyl ring(s) are attached or fused to the aromatic; R^4 is selected from the group consisting of hydrogen, halogen, substituted or unsubstituted C_1-C_6 alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; R^1 and R^2 are each independently selected from the group

consisting of halogen, substituted or unsubstituted C_1-C_4 alkyl, and substituted or unsubstituted C_3-C_5 cycloalkyl; R^7 is selected selected from the group consisting of hydrogen, halogen, amino, hydroxyl, -O-C_1-C_4 alkyl, -SH and -S-C_1-C_4 alkyl; and R^5 is selected from the group consisting of hydroxyl, optionally substituted -OC_1-C_6 alkyl, and -OC(O)R^e; then X is not -P(O)(OH)$_2$.

In one aspect, the present invention relates to compounds of Formula I:



wherein:

G is selected from the group consisting of -O-, -S-, -S(=O)-, -S(=O)$_2$-, -CH$_2$-, -CF$_2$-, -CHF-, -C(O)-, -CH(OH)-, -NH-, and -N(C_1-C_4 alkyl)-;

T is selected from the group consisting of -$(CR^a_2)_k$-, -CR^b=CR^b-$(CR^a_2)_n$-, -$(CR^a_2)_n$-CR^b=CR^b-, -(CR^a_2)-CR^b=CR^b-(CR^a_2)-, -O$(CR^b_2)(CR^a_2)_n$-, -S$(CR^b_2)(CR^a_2)_n$-, -N$(R^b)(CR^b_2)(CR^a_2)_n$-, -N(R^b)C(O)$(CR^a_2)_n$-, -$(CR^a_2)_n$CH(NR^bR^c)-, -C(O)$(CR^a_2)_m$-, -$(CR^a_2)_m$C(O)-, -(CR^a_2)C(O)$(CR^a_2)_n$-, -$(CR^a_2)_n$C(O)(CR^a_2)-, and -C(O)NH$(CR^b_2)(CR^a_2)_p$-;

k is an integer from 0-4;

m is an integer from 0-3;

n is an integer from 0-2;

p is an integer from 0-1;

Each R^a is independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_4 alkyl, halogen, -OH, optionally substituted -O-C_1-C_4 alkyl, -OCF$_3$, optionally substituted -S-C_1-C_4 alkyl, -NR^{b}R^c, optionally substituted -C_2-C_4 alkenyl, and optionally substituted -C_2-C_4 alkynyl; with the proviso that when one R^a is attached through O, S, or N, then the other R^a attached to the same C is a hydrogen, or attached via carbon atom.Each R^b is independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_4 alkyl;

Each R^c is independently selected from the group consisting of hydrogen and optionally substituted -C_1-C_4 alkyl, optionally substituted -C(O)-C_1-C_4 alkyl, and -C(O)H;

R^1 and R^2 are each independently selected from the group consisting of halogen, optionally substituted $-C_1-C_4$ alkyl, optionally substituted $-S-C_1-C_3$ alkyl, optionally substituted $-C_2-C_4$ alkenyl, optionally substituted $-C_2-C_4$ alkynyl, $-CF_3$, $-OCF_3$, optionally substituted-$O-C_1-C_3$ alkyl, and cyano;

R^3 and R^4 are each independently selected from the group consisting of hydrogen, halogen, $-CF_3$, $-OCF_3$, cyano, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a{}_2)_m$aryl, optionally substituted $-(CR^a{}_2)_m$cycloalkyl, optionally substituted $-(CR^a{}_2)_m$heterocycloalkyl, $-OR^d$, $-SR^d$, $-S(=O)R^e$, $-S(=O)_2R^e$, $-S(=O)_2NR^fR^g$, $-C(O)NR^fR^g$, $-C(O)OR^h$, $-C(O)R^e$, $-N(R^b)C(O)R^e$, $-N(R^b)C(O)NR^fR^g$, $-N(R^b)S(=O)_2R^e$, $-N(R^b)S(=O)_2NR^fR^g$, and $-NR^fR^g$;

Each R^d is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted, $-(CR^b{}_2)_n$aryl, optionally substituted, $-(CR^b{}_2)_n$cycloalkyl, optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl, and $-C(O)NR^fR^g$;

Each R^e is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a{}_2)_n$aryl, optionally substituted, $-(CR^a{}_2)_n$cycloalkyl, and optionally substituted $-(CR^a{}_2)_n$heterocycloalkyl;

R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, and optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl, or R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup selected from the group of O, NR^c, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-4 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$;

Each R^h is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, and optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl;

R^5 is selected from the group consisting of -OH, optionally substituted -OC_1-C_6 alkyl, -OC(O)R^e, -OC(O)OR^h, -F, -NHC(O)R^e, -NHS(=O)R^e, -NHS(=O)$_2R^e$, -NHC(=S)NH(R^h), and -NHC(O)NH(R^h);

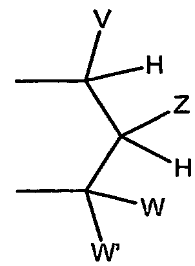
X is P(O)YR^{11}Y'R^{11};

Y and Y' are each independently selected from the group consisting of -O-, and -NR^v-; when Y and Y' are -O- , R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, -C(R^z)$_2$OC(O)N$R^z{}_2$, -NR^z-C(O)-R^y, -C(R^z)$_2$- OC(O)R^y, -C(R^z)$_2$-O-C(O)OR^y, -C(R^z)$_2$OC(O)SR^y, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, nd -alkyl-S-S-S-alkylhydroxy;

when Y and Y' are -NR^v-, then R^{11} attached to -NR^v- is independently selected from the group consisting of -H, -[C(R^z)$_2$]$_q$-COOR^y, -C(R^x)$_2$COOR^y, -[C(R^z)$_2$]$_q$-C(O)SR^y, and -cycloalkylene-COOR^y;

when Y is -O- and Y' is NR^v, then R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, -C(R^z)$_2$OC(O)N$R^z{}_2$, -NR^z-C(O)-R^y, -C(R^z)$_2$- OC(O)R^y, -C(R^z)$_2$-O-C(O)OR^y, -C(R^z)$_2$OC(O)SR^y, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy; and R^{11} attached to -NR^v- is independently selected from the group consisting of -H, -[C(R^z)$_2$]$_q$-COOR^y, -C(R^x)$_2$COOR^y, -[C(R^z)$_2$]$_q$-C(O)SR^y, and -cycloalkylene-COOR^y;

or when Y and Y' are independently selected from -O- and -NR^v-, then together R^{11} and R^{11} are -alkyl-S-S-alkyl- to form a cyclic group, or together R^{11} and R^{11} are the group:



wherein:

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy, alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, that is fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0–2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of -CHR^{z}OH, -CHR^{z}OC(O)R^y, -CHR^{z}OC(S)R^y, -CHR^{z}OC(S)OR^y, -CHR^{z}OC(O)SR^y, -CHR^{z}OCO$_2$R^y, -OR^z,

$-SR^z$, $-CHR^zN_3$, $-CH_2aryl$, -CH(aryl)OH, $-CH(CH{=}CR^z_2)OH$, $-CH(C{\equiv}CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2NHaryl$, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl;

Each R^x is independently selected from the group consisting of -H, and alkyl, or together R^x and R^x form a cyclic alkyl group;

Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl.

Rather than specifically excluding a specific compound from the present invention, provisos may used for exclusionary purposes. Examples of independent provisos of the present invention include the following:

a) when G is –O-, T is $-CH_2-$, R^1 and R^2 are each bromo, R^3 is iso propyl, R^4 is hydrogen, and R^5 is –OH, then X is not $-P(O)(OH)_2$ or $-P(O)(OCH_2CH_3)_2$;

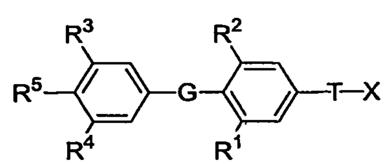
b) V, Z, W, W' are not all -H;

c) when Z is $-R_z$, then at least one of V, W, and W' is not -H, alkyl, aralkyl, or heterocycloalkyl;

d) when G is –O-, T is $-(CH_2)_{0-4}-$, R^1 and R^2 are independently halogen, alkyl of 1 to 3 carbons, and cycloalkyl of 3 to 5 carbons, R^3 is alkyl of 1 to 4 carbons or cycloalkyl of 3 to 7 carbons, R^4 is hydrogen, and R^5 is OH, then X is not $-P(O)(OH)_2$ or -P(O)(O lower alkyl)$_2$; and

e) when G is –O-, R^5 is $-NHC(O)R^e$, $-NHS(=O)_{1-2}R^e$, $-NHC(S)NH(R^h)$, or $-NHC(O)NH(R^h)$, T is $-(CH_2)_m-$, -CH=CH-, $-O(CH_2)_{1-2}-$, or $-NH(CH_2)_{1-2}-$, then X is not $-P(O)(OH)_2$ or $-P(O)(OH)NH_2$.

In one aspect, the present invention relates to compounds of Formula I:



wherein:

G is selected from the group consisting of -O-, -S-, -S(=O)-, $-S(=O)_2-$, $-CH_2-$, $-CF_2-$, -CHF-, -C(O)-, -CH(OH)-, -NH-, and -N(C_1-C_4 alkyl)-;

T is selected from the group consisting of $-(CR^a_2)_k-$, $-CR^b=CR^b-(CR^a_2)_n-$, $-(CR^a_2)_n-CR^b=CR^b-$, $-(CR^a_2)-CR^b=CR^b-(CR^a_2)-$, $-O(CR^b_2)(CR^a_2)_n-$, $-S(CR^b_2)(CR^a_2)_n-$, $-N(R^b)(CR^b_2)(CR^a_2)_n-$, $-N(R^b)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nCH(NR^bR^c)-$, $-C(O)(CR^a_2)_m-$, $-(CR^a_2)_mC(O)-$, $-(CR^a_2)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nC(O)(CR^a_2)-$, and $-C(O)NH(CR^b_2)(CR^a_2)_p-$;

k is an integer from 0-4;

m is an integer from 0-3;

n is an integer from 0-2;

p is an integer from 0-1;

Each R^a is independently selected from the group consisting of hydrogen, optionally substituted $-C_1$-C_4 alkyl, halogen, -OH, optionally substituted $-O-C_1$-C_4 alkyl, $-OCF_3$, optionally substituted $-S-C_1$-C_4 alkyl, $-NR^bR^c$, optionally substituted $-C_2$-C_4 alkenyl, and optionally substituted $-C_2$-C_4 alkynyl; with the proviso that when one R^a is attached through O, S, or N, then the other R^a attached to the same C is a hydrogen, or attached via carbon atom.Each R^b is independently selected from the group consisting of hydrogen, optionally substituted $-C_1$-C_4 alkyl;

Each R^c is independently selected from the group consisting of hydrogen and optionally substituted $-C_1$-C_4 alkyl, optionally substituted $-C(O)-C_1$-C_4 alkyl, and -C(O)H;

R^1 and R^2 are each independently selected from the group consisting of halogen, optionally substituted $-C_1$-C_4 alkyl, optionally substituted $-S-C_1$-C_3 alkyl, optionally substituted $-C_2$-C_4 alkenyl, optionally substituted $-C_2$-C_4 alkynyl, $-CF_3$, $-OCF_3$, optionally substituted-$O-C_1$-C_3 alkyl, and cyano;

R^3 and R^4 are each independently selected from the group consisting of hydrogen, halogen, $-CF_3$, $-OCF_3$, cyano, optionally substituted $-C_1$-C_{12} alkyl, optionally substituted $-C_2$-C_{12} alkenyl, optionally substituted $-C_2$-C_{12} alkynyl, optionally substituted $-(CR^a_2)_m$aryl, optionally substituted $-(CR^a_2)_m$cycloalkyl, optionally substituted $-(CR^a_2)_m$heterocycloalkyl, $-OR^d$, $-SR^d$, $-S(=O)R^e$, $-S(=O)_2R^e$, $-S(=O)_2NR^fR^g$, $-C(O)NR^fR^g$, $-C(O)OR^h$, $-C(O)R^e$, $-N(R^b)C(O)R^e$, $-N(R^b)C(O)NR^fR^g$, $-N(R^b)S(=O)_2R^e$, $-N(R^b)S(=O)_2NR^fR^g$, and $-NR^fR^g$;

Each R^d is selected from the group consisting of optionally substituted $-C_1$-C_{12} alkyl, optionally substituted $-C_2$-C_{12} alkenyl, optionally substituted $-C_2$-C_{12} alkynyl,

optionally substituted, -$(CR^b{}_2)_n$aryl, optionally substituted, -$(CR^b{}_2)_n$cycloalkyl, optionally substituted -$(CR^b{}_2)_n$heterocycloalkyl, and -C(O)NR^fR^g;

Each R^e is selected from the group consisting of optionally substituted -C_1-C_{12} alkyl, optionally substituted -C_2-C_{12} alkenyl, optionally substituted -C_2-C_{12} alkynyl, optionally substituted -$(CR^a{}_2)_n$aryl, optionally substituted, -$(CR^a{}_2)_n$cycloalkyl, and optionally substituted -$(CR^a{}_2)_n$heterocycloalkyl;

R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_{12} alkyl, optionally substituted -C_2-C_{12} alkenyl, optionally substituted -C_2-C_{12} alkynyl, optionally substituted -$(CR^b{}_2)_n$aryl, optionally substituted -$(CR^b{}_2)_n$cycloalkyl, and optionally substituted -$(CR^b{}_2)_n$heterocycloalkyl, or R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup selected from the group of O, NR^c, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-4 substituents selected from the group consisting of optionally substituted -C_1-C_4 alkyl, -OR^b, oxo, cyano, -CF_3, optionally substituted phenyl, and -C(O)OR^h;

Each R^h is selected from the group consisting of optionally substituted -C_1-C_{12} alkyl, optionally substituted -C_2-C_{12} alkenyl, optionally substituted -C_2-C_{12} alkynyl, optionally substituted -$(CR^b{}_2)_n$aryl, optionally substituted -$(CR^b{}_2)_n$cycloalkyl, and optionally substituted -$(CR^b{}_2)_n$heterocycloalkyl;

R^5 is selected from the group consisting of -OH, optionally substituted -OC_1-C_6 alkyl, -OC(O)R^e, -OC(O)OR^h, -F, -NHC(O)R^e, -NHS(=O)R^e, -NHS(=O)$_2R^e$, -NHC(=S)NH(R^h), and -NHC(O)NH(R^h);

X is P(O)$YR^{11}Y'R^{11}$;

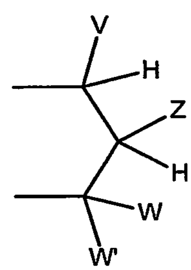
Y and Y' are each independently selected from the group consisting of -O-, and -NR^v-; when Y and Y' are -O- , R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, -$C(R^z)_2OC(O)NR^z{}_2$, -NR^z-C(O)-R^y, -$C(R^z)_2$- OC(O)R^y, -$C(R^z)_2$-O-C(O)OR^y, -$C(R^z)_2OC(O)SR^y$, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, nd -alkyl-S-S-S-alkylhydroxy;

when Y and Y' are -NR^v-, then R^{11} attached to -NR^v- is independently selected from the group consisting

of -H, -[C(R^z)$_2$]$_q$-COOR^y, -C(R^x)$_2$COOR^y, -[C(R^z)$_2$]$_q$-C(O)SR^y, and -cycloalkylene-COOR^y;

when Y is -O- and Y' is NR^v, then R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH$_2$-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, -C(R^z)$_2$OC(O)NR$^z{}_2$, -NR^z-C(O)-R^y, -C(R^z)$_2$- OC(O)R^y, -C(R^z)$_2$-O-C(O)OR^y, -C(R^z)$_2$OC(O)SR^y, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy; and R^{11} attached to -NR^v- is independently selected from the group consisting of -H, -[C(R^z)$_2$]$_q$-COOR^y, -C(R^x)$_2$COOR^y, -[C(R^z)$_2$]$_q$-C(O)SR^y, and -cycloalkylene-COOR^y;

or when Y and Y' are independently selected from -O- and -NR^v-, then together R^{11} and R^{11} are -alkyl-S-S-alkyl- to form a cyclic group, or together R^{11} and R^{11} are the group:



wherein:

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy, alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, that is

fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0–2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of $-CHR^zOH$, $-CHR^zOC(O)R^y$, $-CHR^zOC(S)R^y$, $-CHR^zOC(S)OR^y$, $-CHR^zOC(O)SR^y$, $-CHR^zOCO_2R^y$, $-OR^z$, $-SR^z$, $-CHR^zN_3$, $-CH_2$aryl, -CH(aryl)OH, $-CH(CH{=}CR^z_2)OH$, $-CH(C{\equiv}CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2$NHaryl, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl;

Each R^x is independently selected from the group consisting of -H, and alkyl, or together R^x and R^x form a cyclic alkyl group;

Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl;

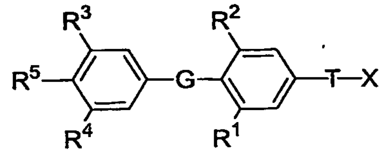
with the provisos that:

a) when G is -O-, T is $-CH_2-$, R^1 and R^2 are each bromo, R^3 is *iso*-propyl, R^4 is hydrogen, and R^5 is –OH, then X is not $P(O)(OH)_2$ or $P(O)(OCH_2CH_3)_2$;

b) V, Z, W, W' are not all -H; and

c) when Z is $-R^z$, then at least one of V, W, and W' is not -H, alkyl, aralkyl, or heterocycloalkyl;.

In another aspect, the invention comprises a compound of Formula I:



wherein:

G is selected from the group consisting of -O-, -S-, -S(=O)-, -S(=O)$_2$-, -CH$_2$-, -CF$_2$-, -CHF-, -C(O)-, -CH(OH)-, -NH-, and -N(C$_1$-C$_4$ alkyl)-;

T is selected from the group consisting of -(CR$^a_2$)$_k$-, -CR^b=CR^b-(CR$^a_2$)$_n$-, -(CR$^a_2$)$_n$-CR^b=CR^b-, -(CR$^a_2$)-CR^b=CR^b-(CR$^a_2$)-, -(CR,-(CR$^b_2$)(CR$^a_2$)$_n$-, -S(CR$^b_2$)(CR$^a_2$)$_n$-, -N(R^c)(CR$^b_2$)(CR$^a_2$)$_n$-, -N(R^b)C(O)(CR$^a_2$)$_n$-, -(CR$^a_2$)$_n$CH(NR^{b}R^c)-, -C(O)(CR$^a_2$)$_m$-, -(CR$^a_2$)$_m$C(O)-, -(CR$^a_2$)C(O)(CR$^a_2$)$_n$-, -(CR$^a_2$)$_n$C(O)(CR$^a_2$)-, and -C(O)NH(CR$^b_2$)(CR$^a_2$)$_p$-;

k is an integer from 0-4;

m is an integer from 0-3;

n is an integer from 0-2;

p is an integer from 0-1;

Each R^a is independently selected from the group consisting of hydrogen, optionally substituted -C$_1$-C$_4$ alkyl, halogen, -OH, optionally substituted -O-C$_1$-C$_4$ alkyl, -OCF$_3$, optionally substituted -S-C$_1$-C$_4$ alkyl, -NR^{b}R^c, optionally substituted -C$_2$-C$_4$ alkenyl, and optionally substituted -C$_2$-C$_4$ alkynyl; with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom;

Each R^b is independently selected from the group consisting of hydrogen, optionally substituted -C$_1$-C$_4$ alkyl;

Each R^c is independently selected from the group consisting of hydrogen and optionally substituted -C$_1$-C$_4$ alkyl, optionally substituted -C(O)-C$_1$-C$_4$ alkyl, and -C(O)H;

R^1 and R^2 are each independently selected from the group consisting of halogen, optionally substituted -C$_1$-C$_4$ alkyl, optionally substituted -S-C$_1$-C$_3$ alkyl, optionally substituted -C$_2$-C$_4$ alkenyl, optionally substituted -C$_2$-C$_4$ alkynyl, -CF$_3$, -OCF$_3$, optionally substituted-O-C$_1$-C$_3$ alkyl, and cyano;

R^3 and R^4 are each independently selected from the group consisting of hydrogen, halogen, $-CF_3$, $-OCF_3$, cyano, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a{}_2)_m$aryl, optionally substituted $-(CR^a{}_2)_m$cycloalkyl, optionally substituted $-(CR^a{}_2)_m$heterocycloalkyl, $-OR^d$, $-SR^d$, $-S(=O)R^e$, $-S(=O)_2R^e$, $-S(=O)_2NR^fR^g$, $-C(O)NR^fR^g$, $-C(O)OR^h$, $-C(O)R^e$, $-N(R^b)C(O)R^e$, $-N(R^b)C(O)NR^fR^g$, $-N(R^b)S(=O)_2R^e$, $-N(R^b)S(=O)_2NR^fR^g$, and $-NR^fR^g$;

Each R^d is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl, and $-C(O)NR^fR^g$;

Each R^e is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a{}_2)_n$aryl, optionally substituted $-(CR^a{}_2)_n$cycloalkyl, and optionally substituted $-(CR^a{}_2)_n$heterocycloalkyl;

R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, and optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl, or R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup selected from the group consisting of O, NR^c, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-4 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$;

Each R^h is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, and optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl;

R^5 is selected from the group consisting of -OH, optionally substituted $-OC_1-C_6$ alkyl, $-OC(O)R^e$, $-OC(O)OR^h$, -F, $-NHC(O)R^e$, $-NHS(=O)R^e$, $-NHS(=O)_2R^e$, $-NHC(=S)NH(R^h)$, and $-NHC(O)NH(R^h)$;

X is $P(O)YR^{11}Y'R^{11}$;

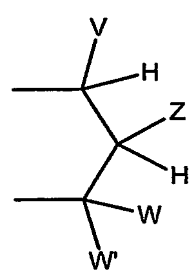
Y and Y' are each independently selected from the group consisting of -O-, and $-NR^v-$; when Y and Y' are -O- , R^{11} attached to -O- is independently selected from

the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, $-C(R^z)_2OC(O)NR^z_2$, $-NR^z-C(O)-R^y$, $-C(R^z)_2-OC(O)R^y$, $-C(R^z)_2-O-C(O)OR^y$, $-C(R^z)_2OC(O)SR^y$, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy;

when Y and Y' are $-NR^v-$, then R^{11} attached to $-NR^v-$ is independently selected from the group consisting of -H, $-[C(R^z)_2]_q-COOR^y$, $-C(R^x)_2COOR^y$, $-[C(R^z)_2]_q-C(O)SR^y$, and -cycloalkylene-$COOR^y$;

when Y is -O- and Y' is NR^v, then R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, $-C(R^z)_2OC(O)NR^z_2$, $-NR^z-C(O)-R^y$, $-C(R^z)_2-OC(O)R^y$, $-C(R^z)_2-O-C(O)OR^y$, $-C(R^z)_2OC(O)SR^y$, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy; and R^{11} attached to $-NR^v-$ is independently selected from the group consisting of -H, $-[C(R^z)_2]_q-COOR^y$, $-C(R^x)_2COOR^y$, $-[C(R^z)_2]_q-C(O)SR^y$, and -cycloalkylene-$COOR^y$;

or when Y and Y' are independently selected from -O- and $-NR^v-$, then together R^{11} and R^{11} are -alkyl-S-S-alkyl- to form a cyclic group, or together R^{11} and R^{11} are the group:



wherein:

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy, alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, that is fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0–2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of $-CHR^zOH$, $-CHR^zOC(O)R^y$, $-CHR^zOC(S)R^y$, $-CHR^zOC(S)OR^y$, $-CHR^zOC(O)SR^y$, $-CHR^zOCO_2R^y$, $-OR^z$, $-SR^z$, $-CHR^zN_3$, $-CH_2aryl$, -CH(aryl)OH, $-CH(CH{=}CR^z_2)OH$, $-CH(C{\equiv}CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2NHaryl$, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl;

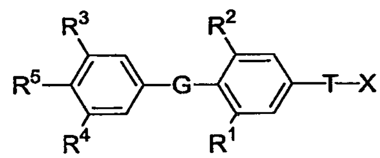
Each R^x is independently selected from the group consisting of -H, and alkyl, or together R^x and R^x form a cyclic alkyl group;

Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl;

with the proviso that when G is -O-, T is $-CH_2-$, R^1 and R^2 are each bromo, R^3 is *iso*-propyl, R^4 is hydrogen, and R^5 is –OH, then X is not $P(O)(OH)_2$ or $P(O)(OCH_2CH_3)_2$;

and pharmaceutically acceptable salts and prodrugs thereof and pharmaceutically acceptable salts of said prodrugs.

In a second aspect the present invention relates to compounds of Formula I, stereoisomers, pharmaceutically acceptable salts and prodrugs thereof and pharmaceutically acceptable salts of the prodrugs as represented by Formula I:



wherein:

G is selected from the group consisting of -O-, -S-, -S(=O)-, $-S(=O)_2-$, $-CH_2-$, $-CF_2-$, -CHF-, -C(O)-, -CH(OH)-, -NH-, and $-N(C_1-C_4$ alkyl)-;

T is selected from the group consisting of $-(CR^a_2)_k-$, $-CR^b=CR^b-(CR^a_2)_n-$, $-(CR^a_2)_n-CR^b=CR^b-$, $-(CR^a_2)-CR^b=CR^b-(CR^a_2)-$, $-O(CR^b_2)(CR^a_2)_n-$, $-S(CR^b_2)(CR^a_2)_n-$, $-N(R^b)(CR^b_2)(CR^a_2)_n-$, $-N(R^b)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nCH(NR^bR^c)-$, $-C(O)(CR^a_2)_m-$, $-(CR^a_2)_mC(O)-$, $-(CR^a_2)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nC(O)(CR^a_2)-$, and $-C(O)NH(CR^b_2)(CR^a_2)_p-$;

k is an integer from 0-4;

m is an integer from 0-3;

n is an integer from 0-2;

p is an integer from 0-1;

Each R^a is independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_4$ alkyl, halogen, -OH, optionally substituted $-O-C_1-C_4$ alkyl, $-OCF_3$, optionally substituted $-S-C_1-C_4$ alkyl, $-NR^bR^c$, optionally substituted $-C_2-C_4$ alkenyl, and optionally substituted $-C_2-C_4$ alkynyl; with the proviso that when one R^a is attached through O, S, or N, then the other R^a attached to the same C is a hydrogen, or attached via carbon atom.

Each R^b is independently selected from the group consisting of hydrogen and optionally substituted $-C_1-C_4$ alkyl;

Each R^c is independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_4$ alkyl, optionally substituted $-C(O)-C_1-C_4$ alkyl, and $-C(O)H$;

R^1 and R^2 are each independently selected from the group consisting of halogen, optionally substituted $-C_1-C_4$ alkyl, optionally substituted $-S-C_1-C_3$ alkyl, optionally substituted $-C_2-C_4$ alkenyl, optionally substituted $-C_2-C_4$ alkynyl, $-CF_3$, $-OCF_3$, optionally substituted-$O-C_1-C_3$ alkyl, and cyano;

R^3 and R^4 are each independently selected from the group consisting of hydrogen, halogen, $-CF_3$, $-OCF_3$, cyano, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a{}_2)_m$aryl, optionally substituted $-(CR^a{}_2)_m$cycloalkyl, optionally substituted $(CR^a{}_2)_m$heterocycloalkyl, $-OR^d$, $-SR^d$, $-S(=O)R^e$, $-S(=O)_2R^e$, $-S(=O)_2NR^fR^g$, $-C(O)NR^fR^g$, $-C(O)OR^h$, $-C(O)R^e$, $-N(R^b)C(O)R^e$, $-N(R^b)C(O)NR^fR^g$, $-N(R^b)S(=O)_2R^e$, $-N(R^b)S(=O)_2NR^fR^g$, and $-NR^fR^g$;

Each R^d is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted, $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl, and $-C(O)NR^fR^g$;

Each R^e is optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a{}_2)_n$aryl, optionally substituted $-(CR^a{}_2)_n$cycloalkyl, and optionally substituted $-(CR^a{}_2)_n$heterocycloalkyl;

R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, and optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl, or R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup selected from the group of O, NR^c, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-4 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$;

Each R^h is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl,

optionally substituted -$(CR^b_2)_n$aryl, optionally substituted -$(CR^b_2)_n$cycloalkyl, and optionally substituted -$(CR^b_2)_n$heterocycloalkyl;

R^5 is selected from the group consisting of -OH, optionally substituted -OC_1-C_6 alkyl, -OC(O)R^e, -OC(O)OR^h, -F, -NHC(O)R^e, -NHS(=O)R^e, -NHS(=O)$_2R^e$, -NHC(=S)NH(R^h), and -NHC(O)NH(R^h);

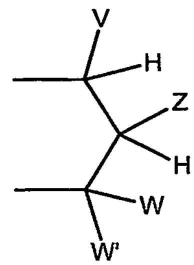
X is P(O)YR^{11}Y'R^{11};

Y and Y' are each independently selected from the group consisting of -O-, and -NR^v-; when Y and Y' are -O- , R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, -C(R^z)$_2$OC(O)NR^z_2, -NR^z-C(O)-R^y, -C(R^z)$_2$- OC(O)R^y, -C(R^z)$_2$-O-C(O)OR^y, -C(R^z)$_2$OC(O)SR^y, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy;

when Y and Y' are -NR^v-, then R^{11} attached to -NR^v- is independently selected from the group consisting of -H, -[C(R^z)$_2$]$_q$-COOR^y, -C(R^x)$_2$COOR^y, -[C(R^z)$_2$]$_q$-C(O)SR^y, and -cycloalkylene-COOR^y;

when Y is -O- and Y' is NR^v, then R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, -C(R^z)$_2$OC(O)NR^z_2, -NR^z-C(O)-R^y, -C(R^z)$_2$- OC(O)R^y, -C(R^z)$_2$-O-C(O)OR^y, -C(R^z)$_2$OC(O)SR^y, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy; and R^{11} attached to -NR^v- is independently selected from the group consisting of -H, -[C(R^z)$_2$]$_q$-COOR^y, -C (R^x)$_2$COOR^y, -[C(R^z)$_2$]$_q$-C(O)SR^y, and -cycloalkylene-COOR^y;

or when Y and Y' are independently selected from -O- and -NR^v-, then together R^{11} and R^{11} are -alkyl-S-S-alkyl- to form a cyclic group, or together R^{11} and R^{11} are the group:



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wherein:

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0 – 1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy, alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0 – 1 atoms are heteroatoms and the remaining atoms are carbon, that is fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0 – 1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0 – 2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of $-CHR^zOH$, $-CHR^zOC(O)R^y$, $-CHR^zOC(S)R^y$, $-CHR^zOC(S)OR^y$, $-CHR^zOC(O)SR^y$, $-CHR^zOCO_2R^y$, $-OR^z$,

$-SR^z$, $-CHR^zN_3$, $-CH_2$aryl, -CH(aryl)OH, $-CH(CH{=}CR^z_2)OH$, $-CH(C{\equiv}CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2NH$aryl, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl;

Each R^x is independently selected from the group consisting of -H, and alkyl, or together R^x and R^x form a cyclic alkyl group;

Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl;

with the provisos that:

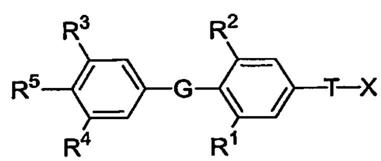
a) when G is -O-, T is $-(CH_2)_{0\text{-}4}-$, R^1 and R^2 are independently halogen, alkyl of 1 to 3 carbons, and cycloalkyl of 3 to 5 carbons, R^3 is alkyl of 1 to 4 carbons or cycloalkyl of 3 to 7 carbons, R^4 is hydrogen, and R^5 is -OH, then X is not $-P(O)(OH)_2$ or $-P(O)(O\text{-lower alkyl})_2$;

b) when G is -O-, R^5 is $-NHC(O)R^e$, $-NHS(=O)_{1\text{-}2}R^e$, $-NHC(S)NH(R^h)$, or $-NHC(O)NH(R^h)$, T is $-(CH_2)_m-$, -CH=CH-, $-O(CH_2)_{1\text{-}2}-$, or $-NH(CH_2)_{1\text{-}2}-$, then X is not $-P(O)(OH)_2$ or $-P(O)(OH)NH_2$;

c) V, Z, W, W' are not all -H; and

d) when Z is $-R^z$, then at least one of V, W, and W' is not -H, alkyl, aralkyl, or heterocycloalkyl.

In a further aspect, the present invention relates to compounds of Formula I, stereoisomers, pharmaceutically acceptable salts and prodrugs thereof and pharmaceutically acceptable salts of the prodrugs as represented by Formula I:



wherein:

G is selected from the group consisting of -O-, -S-, -S(=O)-, $-S(=O)_2-$, $-CH_2-$, $-CF_2-$, -CHF-, -C(O)-, -CH(OH)-, -NH-, and $-N(C_1\text{-}C_4\text{ alkyl})-$;

T is selected from the group consisting of $-(CR^a_2)_k-$, $-CR^b=CR^b-(CR^a_2)_n-$, $-(CR^a_2)_n-CR^b=CR^b-$, $-(CR^a_2)-CR^b=CR^b-(CR^a_2)-$, $-O(CR^b_2)(CR^a_2)_n-$, $-S(CR^b_2)(CR^a_2)_n-$, $-N(R^b)(CR^b_2)(CR^a_2)_n-$, $-N(R^b)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nCH(NR^bR^c)-$, $-C(O)(CR^a_2)_m-$, $-(CR^a_2)_mC(O)-$, $-(CR^a_2)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nC(O)(CR^a_2)-$, and $-C(O)NH(CR^b_2)(CR^a_2)_p-$;

k is an integer from 0-4;

m is an integer from 0-3;

n is an integer from 0-2;

p is an integer from 0-1;

Each R^a is independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_4$ alkyl, halogen, -OH, optionally substituted $-O-C_1-C_4$ alkyl, $-OCF_3$, optionally substituted $-S-C_1-C_4$ alkyl, $-NR^bR^c$, optionally substituted $-C_2-C_4$ alkenyl, and optionally substituted $-C_2-C_4$ alkynyl; with the proviso that when one R^a is attached through O, S, or N, then the other R^a attached to the same C is a hydrogen, or attached via carbon atom.

Each R^b is independently selected from the group consisting of hydrogen and optionally substituted $-C_1-C_4$ alkyl;

Each R^c is independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_4$ alkyl, optionally substituted $-C(O)-C_1-C_4$ alkyl, and -C(O)H;

R^1 and R^2 are each independently selected from the group consisting of halogen, optionally substituted $-C_1-C_4$ alkyl, optionally substituted $-S-C_1-C_3$ alkyl, optionally substituted $-C_2-C_4$ alkenyl, optionally substituted $-C_2-C_4$ alkynyl, $-CF_3$, $-OCF_3$, optionally substituted-$O-C_1-C_3$ alkyl, and cyano;

R^3 and R^4 are each independently selected from the group consisting of hydrogen, halogen, $-CF_3$, $-OCF_3$, cyano, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a_2)_m$aryl, optionally substituted $-(CR^a_2)_m$cycloalkyl, optionally substituted $(CR^a_2)_m$heterocycloalkyl, $-OR^d$, $-SR^d$, $-S(=O)R^e$, $-S(=O)_2R^e$, $-S(=O)_2NR^fR^g$, $-C(O)NR^fR^g$, $-C(O)OR^h$, $-C(O)R^e$, $-N(R^b)C(O)R^e$, $-N(R^b)C(O)NR^fR^g$, $-N(R^b)S(=O)_2R^e$, $-N(R^b)S(=O)_2NR^fR^g$, and $-NR^fR^g$;

Each R^d is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl,

optionally substituted, $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl, and $-C(O)NR^fR^g$;

Each R^e is optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a{}_2)_n$aryl, optionally substituted $-(CR^a{}_2)_n$cycloalkyl, and optionally substituted $-(CR^a{}_2)_n$heterocycloalkyl;

R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, and optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl, or R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup selected from the group of O, NR^c, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-4 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$;

Each R^h is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, and optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl;

R^5 is selected from the group consisting of -OH, optionally substituted $-OC_1-C_6$ alkyl, $-OC(O)R^e$, $-OC(O)OR^h$, -F, $-NHC(O)R^e$, $-NHS(=O)R^e$, $-NHS(=O)_2R^e$, $-NHC(=S)NH(R^h)$, and $-NHC(O)NH(R^h)$;

X is $P(O)YR^{11}Y'R^{11}$;

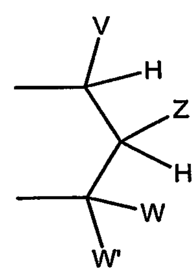
Y and Y' are each independently selected from the group consisting of -O-, and $-NR^v-$; when Y and Y' are -O- , R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, $-C(R^z)_2OC(O)NR^z{}_2$, $-NR^z-C(O)-R^y$, $-C(R^z)_2-OC(O)R^y$, $-C(R^z)_2-O-C(O)OR^y$, $-C(R^z)_2OC(O)SR^y$, $-alkyl-S-C(O)R^y$, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy;

when Y and Y' are $-NR^v-$, then R^{11} attached to $-NR^v-$ is independently selected from the group consisting

of -H, -[C(R^z)$_2$]$_q$-COOR^y, -C(R^x)$_2$COOR^y, -[C(R^z)$_2$]$_q$-C(O)SR^y, and -cycloalkylene-COOR^y;

when Y is -O- and Y' is NR^v, then R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH$_2$-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, -C(R^z)$_2$OC(O)NR$^z{}_2$, -NR^z-C(O)-R^y, -C(R^z)$_2$- OC(O)R^y, -C(R^z)$_2$-O-C(O)OR^y, -C(R^z)$_2$OC(O)SR^y, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy; and R^{11} attached to -NR^v- is independently selected from the group consisting of -H, -[C(R^z)$_2$]$_q$-COOR^y, -C (R^x)$_2$COOR^y, -[C(R^z)$_2$]$_q$-C(O)SR^y, and -cycloalkylene-COOR^y;

or when Y and Y' are independently selected from -O- and -NR^v-, then together R^{11} and R^{11} are -alkyl-S-S-alkyl- to form a cyclic group, or together R^{11} and R^{11} are the group:



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wherein:

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0 – 1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy, alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0 – 1 atoms are heteroatoms and the remaining atoms are carbon, that is

fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0 – 1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0 – 2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of $-CHR^zOH$, $-CHR^zOC(O)R^y$, $-CHR^zOC(S)R^y$, $-CHR^zOC(S)OR^y$, $-CHR^zOC(O)SR^y$, $-CHR^zOCO_2R^y$, $-OR^z$, $-SR^z$, $-CHR^zN_3$, $-CH_2$aryl, -CH(aryl)OH, $-CH(CH=CR^z_2)OH$, $-CH(C\equiv CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2$NHaryl, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl;

Each R^x is independently selected from the group consisting of -H, and alkyl, or together R^x and R^x form a cyclic alkyl group;

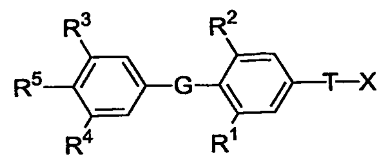
Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl;

with the provisos that:

a) V, Z, W, W' are not all -H; and

b) when Z is $-R^z$, then at least one of V, W, and W' is not -H, alkyl, aralkyl, or heterocycloalkyl.

In another aspect, the invention comprises a compound of Formula I:



wherein:

G is selected from the group consisting of -O-, -S-, -S(=O)-, $-S(=O)_2-$, $-CH_2-$, $-CF_2-$, -CHF-, -C(O)-, -CH(OH)-, -NH-, and -N(C_1-C_4 alkyl)-;

T is selected from the group consisting of $-(CR^a_2)_k-$, $-CR^b=CR^b-(CR^a_2)_n-$, $-(CR^a_2)_n-CR^b=CR^b-$, $-(CR^a_2)-CR^b=CR^b-(CR^a_2)-$, $-O(CR^b_2)(CR^a_2)_n-$, $-S(CR^b_2)(CR^a_2)_n-$, $-N(R^c)(CR^b_2)(CR^a_2)_n-$, $-N(R^b)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nCH(NR^bR^c)-$, $-C(O)(CR^a_2)_m-$, $-(CR^a_2)_mC(O)-$, $-(CR^a_2)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nC(O)(CR^a_2)-$, and $-C(O)NH(CR^b_2)(CR^a_2)_p-$;

k is an integer from 0-4;

m is an integer from 0-3;

n is an integer from 0-2;

p is an integer from 0-1;

Each R^a is independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_4 alkyl, halogen, -OH, optionally substituted -O-C_1-C_4 alkyl, $-OCF_3$, optionally substituted -S-C_1-C_4 alkyl, $-NR^bR^c$, optionally substituted -C_2-C_4 alkenyl, and optionally substituted -C_2-C_4 alkynyl; with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom;

Each R^b is independently selected from the group consisting of hydrogen and optionally substituted -C_1-C_4 alkyl;

Each R^c is independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_4 alkyl, optionally substituted -C(O)-C_1-C_4 alkyl, and -C(O)H;

R^1 and R^2 are each independently selected from the group consisting of halogen, optionally substituted -C_1-C_4 alkyl, optionally substituted -S-C_1-C_3 alkyl, optionally substituted -C_2-C_4 alkenyl, optionally substituted -C_2-C_4 alkynyl, $-CF_3$, $-OCF_3$, optionally substituted-O-C_1-C_3 alkyl, and cyano;

R^3 and R^4 are each independently selected from the group consisting of hydrogen, halogen, $-CF_3$, $-OCF_3$, cyano, optionally substituted -C_1-C_{12} alkyl, optionally substituted -C_2-C_{12} alkenyl, optionally substituted -C_2-C_{12} alkynyl, optionally

substituted $-(CR^a_2)_m$aryl, optionally substituted $-(CR^a_2)_m$cycloalkyl, optionally substituted $(CR^a_2)_m$heterocycloalkyl, $-OR^d$, $-SR^d$, $-S(=O)R^e$, $-S(=O)_2R^e$, $-S(=O)_2NR^fR^g$, $-C(O)NR^fR^g$, $-C(O)OR^h$, $-C(O)R^e$, $-N(R^b)C(O)R^e$, $-N(R^b)C(O)NR^fR^g$, $-N(R^b)S(=O)_2R^e$, $-N(R^b)S(=O)_2NR^fR^g$, and $-NR^fR^g$;

Each R^d is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b_2)_n$aryl, optionally substituted $-(CR^b_2)_n$cycloalkyl, optionally substituted $-(CR^b_2)_n$heterocycloalkyl, and $-C(O)NR^fR^g$;

Each R^e is optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a_2)_n$aryl, optionally substituted $-(CR^a_2)_n$cycloalkyl, and optionally substituted $-(CR^a_2)_n$heterocycloalkyl;

R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b_2)_n$aryl, optionally substituted $-(CR^b_2)_n$cycloalkyl, and optionally substituted $-(CR^b_2)_n$heterocycloalkyl, or R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup selected from the group of O, NR^c, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-4 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$;

Each R^h is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b_2)_n$aryl, optionally substituted $-(CR^b_2)_n$cycloalkyl, and optionally substituted $-(CR^b_2)_n$heterocycloalkyl;

R^5 is selected from the group consisting of -OH, optionally substituted $-OC_1-C_6$ alkyl, $-OC(O)R^e$, $-OC(O)OR^h$, -F, $-NHC(O)R^e$, $-NHS(=O)R^e$, $-NHS(=O)_2R^e$, $-NHC(=S)NH(R^h)$, and $-NHC(O)NH(R^h)$;

X is $P(O)YR^{11}Y'R^{11}$;

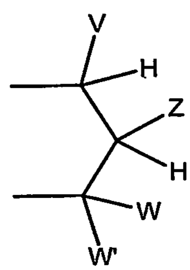
Y and Y' are each independently selected from the group consisting of -O-, and $-NR^v-$; when Y and Y' are -O- , R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl,

$-C(R^z)_2OC(O)NR^z_2$, $-NR^z-C(O)-R^y$, $-C(R^z)_2-OC(O)R^y$, $-C(R^z)_2-O-C(O)OR^y$, $-C(R^z)_2OC(O)SR^y$, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy;

when Y and Y' are $-NR^v-$, then R^{11} attached to $-NR^v-$ is independently selected from the group consisting of -H, $-[C(R^z)_2]_q-COOR^y$, $-C(R^x)_2COOR^y$, $-[C(R^z)_2]_q-C(O)SR^y$, and -cycloalkylene-$COOR^y$;

when Y is -O- and Y' is NR^v, then R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, $-C(R^z)_2OC(O)NR^z_2$, $-NR^z-C(O)-R^y$, $-C(R^z)_2-OC(O)R^y$, $-C(R^z)_2-O-C(O)OR^y$, $-C(R^z)_2OC(O)SR^y$, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy; and R^{11} attached to $-NR^v-$ is independently selected from the group consisting of -H, $-[C(R^z)_2]_q-COOR^y$, $-C(R^x)_2COOR^y$, $-[C(R^z)_2]_q-C(O)SR^y$, and -cycloalkylene-$COOR^y$;

or when Y and Y' are independently selected from -O- and $-NR^v-$, then together R^{11} and R^{11} are -alkyl-S-S-alkyl- to form a cyclic group, or together R^{11} and R^{11} are the group:



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wherein:

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0 – 1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy,

alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, that is fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0–2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of $-CHR^zOH$, $-CHR^zOC(O)R^y$, $-CHR^zOC(S)R^y$, $-CHR^zOC(S)OR^y$, $-CHR^zOC(O)SR^y$, $-CHR^zOCO_2R^y$, $-OR^z$, $-SR^z$, $-CHR^zN_3$, $-CH_2aryl$, -CH(aryl)OH, $-CH(CH{=}CR^z_2)OH$, $-CH(C{\equiv}CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2NHaryl$, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl;

Each R^x is independently selected from the group consisting of -H, and alkyl, or together R^x and R^x form a cyclic alkyl group;

Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl;

with the provisos that:

a) when G is -O-, T is $-(CH_2)_{0-4}-$, R^1 and R^2 are independently halogen, alkyl of 1 to 3 carbons, and cycloalkyl of 3 to 5 carbons, R^3 is alkyl of 1 to 4 carbons or

cycloalkyl of 3 to 7 carbons, R^4 is hydrogen, and R^5 is -OH, then X is not -P(O)(OH)$_2$ or -P(O)(O-lower alkyl)$_2$;

b) when G is -O-, R^5 is -NHC(O)R^e, -NHS(=O)$_{1-2}R^e$, -NHC(S)NH(R^h), or -NHC(O)NH(R^h), T is -(CH$_2$)$_m$-, -CH=CH-, -O(CH$_2$)$_{1-2}$-, or -NH(CH$_2$)$_{1-2}$-, then X is not -P(O)(OH)$_2$ or -P(O)(OH)NH$_2$;

and pharmaceutically acceptable salts and prodrugs thereof and pharmaceutically acceptable salts of said prodrugs.

In one aspect, G is -O-. In another aspect, G is -CH$_2$-. In yet another aspect, G is selected from the group consisting of -O- and -CH$_2$-. In another aspect, G is -S-. In a further aspect, G is -S(=O)-. In another aspect, G is -S(=O)$_2$-. In a further aspect, G is -CH$_2$-. In another aspect, G is -CF$_2$-. In a further aspect, G is -CHF-. In another aspect, G is -C(O)-. In another aspect, G is -CH(OH)-. In a further aspect, G is -NH-. In another aspect, G is -N(C_1-C_4 alkyl)-. In yet another aspect, G is selected from the group consisting of -O-, -S- and -CH$_2$-.

In one aspect, T is T is -CH$_2$-. In another aspect, T is -(CH$_2$)$_{0-4}$-. In another aspect, T is selected from the group consisting of -(CH$_2$)$_m$-, -CH=CH-, -O(CH$_2$)$_{1-2}$-, and -NH(CH$_2$)$_{1-2}$-. In yet another aspect, T is selected from the group consisting of -(CR^a_2)$_n$-, -O(CR^b_2)(CR^a_2)$_p$-, -N(R^c)(CR^b_2)(CR^a_2)$_p$-, -S(CR^b_2)(CR^a_2)$_p$-, -NR^b(CO)-, and -CH$_2$CH(NR^cR^b)-. In another aspect, T is -CH$_2$CH(NH$_2$)-. In another aspect, T is -N(H)C(O)-. In a further aspect, T is -OCH$_2$-. In another aspect, T is -CH$_2$CH$_2$-. In yet another aspect, T is -CH$_2$CH(NH$_2$)-. In another aspect, T is -N(H)C(O)-.

In a further aspect, T is -(CR^a_2)$_k$-. In another aspect, T is -CR^b=CR^b-(CR^a_2)$_n$-. In a further aspect, T is -(CR^a_2)$_n$-CR^b=CR^b-. In another aspect, T is -(CR^a_2)-CR^b=CR^b-(CR^a_2)-. In a further aspect, T is -O(CR^b_2)(CR^a_2)$_n$-. In another aspect, T is -S(CR^b_2)(CR^a_2)$_n$-. In a further aspect, T is -N(R^c)(CR^b_2)(CR^a_2)$_n$-. In another aspect, T is -N(R^b)C(O)(CR^a_2)$_n$-. In a further aspect, T is -(CR^a_2)$_n$CH(NR^bR^c)-. In another aspect, T is -C(O)(CR^a_2)$_m$-. In a further aspect, T is -(CR^a_2)$_m$C(O)-. In another aspect, T is -(CR^a_2)C(O)(CR^a_2)$_n$-. In a further aspect, T is -(CR^a_2)$_n$C(O)(CR^a_2)-. In yet another aspect, T is -C(O)NH(CR^b_2)(CR^a_2)$_p$-.

In one aspect k is 0. In a further aspect, k is 1. In an additional aspect, k is 2. In a further aspect, k is 3. In yet another aspect, k is 4. In one aspect m is 0. In a further aspect, m is 1. In an additional aspect, m is 2. In a further aspect, m is 3. In one aspect n is 0. In a further aspect, n is 1. In an additional aspect, n is 2. In one aspect, p is 0. In another aspect, p is 1.

In one aspect, each R^a is hydrogen with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is optionally substituted $-C_1-C_4$ alkyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is halogen with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is –OH with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is optionally substituted $-O-C_1-C_4$ alkyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is $-OCF_3$ with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is optionally substituted $-S-C_1-C_4$ alkyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is $-NR^bR^c$ with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is optionally substituted $-C_2-C_4$ alkenyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is optionally substituted $-C_2-C_4$ alkynyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom.

In one aspect, R^b is hydrogen. In an additional aspect, R^b is optionally substituted $-C_1-C_4$ alkyl.

In one aspect, R^c is hydrogen. In another aspect, R^c is optionally substituted $-C_1-C_4$ alkyl. In a further aspect, R^c is optionally substituted $-C(O)-C_1-C_4$ alkyl. In yet another aspect, R^c is -C(O)H.

In one aspect, R^1 and R^2 are each bromo. In another aspect, R^1 and R^2 are independently selected from the group consisting of hydrogen, halogen, alkyl of 1 to 3 carbons, and cycloalkyl of 3 to 5 carbons. In another aspect, R^1 and R^2 are independently halogen, alkyl of 1 to 3 carbons, and cycloalkyl of 3 to 5 carbons, In a

further aspect, R^1 and R^2 are the same and are selected from the group consisting of halogen, -C_1-C_4 alkyl, -CF_3, and cyano. In an additional aspect, R^1 and R^2 are different and are selected from the group consisting of halogen, -C_1-C_4 alkyl, -CF_3, and cyano. In one aspect, R^1 and R^2 are each independently selected from the group consisting of halogen, -C_1-C_4 alkyl, -CF_3, and cyano. In another aspect, R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano. In another aspect, R^1 and R^2 are each iodo. In one aspect, R^1 and R^2 are each methyl. In a further aspect, R^1 and R^2 are each chloro. In another aspect, R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, and methyl.

In an additional aspect, R^1 and R^2 are each halogen. In another aspect, R^1 and R^2 are each optionally substituted -C_1-C_4 alkyl. In a further aspect, R^1 and R^2 are each optionally substituted -S-C_1-C_3 alkyl. In another aspect, R^1 and R^2 are each optionally substituted -C_2-C_4 alkenyl. In a further aspect, R^1 and R^2 are each optionally substituted -C_2-C_4 alkynyl. In another aspect, R^1 and R^2 are each -CF_3. In a further aspect, R^1 and R^2 are each -OCF_3. In another aspect, R^1 and R^2 are each optionally substituted-O-C_1-C_3 alkyl. In a further aspect, R^1 and R^2 are each cyano.

In yet another aspect, R^3 and R^4 are each hydrogen. In another aspect, R^3 and R^4 are each halogen. In a further aspect, R^3 and R^4 are each -CF_3. In another aspect, R^3 and R^4 are each -OCF_3. In a further aspect, R^3 and R^4 are each cyano. In another aspect, R^3 and R^4 are each optionally substituted -C_1-C_{12} alkyl. In a further aspect, R^3 and R^4 are each optionally substituted -C_2-C_{12} alkenyl. In another aspect, R^3 and R^4 are each optionally substituted -C_2-C_{12} alkynyl. In a further aspect, R^3 and R^4 are each optionally substituted -$(CR^a{}_2)_m$aryl. In another aspect, R^3 and R^4 are each optionally substituted -$(CR^a{}_2)_m$cycloalkyl. In a further aspect, R^3 and R^4 are each optionally substituted -$(CR^a{}_2)_m$heterocycloalkyl. In another aspect, R^3 and R^4 are each -OR^d. In another aspect, R^3 and R^4 are each -SR^d. In a further aspect, R^3 and R^4 are each -S(=O)R^e. In another aspect, R^3 and R^4 are each -$S(=O)_2R^e$. In a further aspect, R^3 and R^4 are each -$S(=O)_2NR^fR^g$. In another aspect, R^3 and R^4 are each -C(O)NR^fR^g. In a further aspect, R^3 and R^4 are each -C(O)OR^h. In another aspect, R^3 and R^4 are each -C(O)R^e. In afurther aspect, R^3 and R^4 are each -N(R^b)C(O)R^e. In another aspect, R^3 and R^4 are each -N(R^b)C(O)NR^fR^g. In a further aspect, R^3 and R^4 are each -N(R^b)$S(=O)_2R^e$. In another aspect, R^3 and R^4 are each -N(R^b)$S(=O)_2NR^fR^g$. In a further aspect, R^3 and R^4 are each -NR^fR^g.

In one aspect, R^4 is selected from the group consisting of hydrogen, halogen, $-C_1$-C_4 alkyl, cyano and CF_3. In another aspect, R^4 is not hydrogen. In a further aspect, R^4 is selected from the group consisting of hydrogen and halogen. In another aspect, R^4 is selected from the group consisting of hydrogen and iodo. In a further aspect, R^4 is hydrogen.

In another aspect, each R^d is optionally substituted $-C_1$-C_{12} alkyl. In a further aspect, each R^d is optionally substituted $-C_2$-C_{12} alkenyl. In another aspect, each R^d is optionally substituted $-C_2$-C_{12} alkynyl. In a further aspect, each R^d is optionally substituted $-(CR^b{}_2)_n$aryl. In another aspect, each R^d is optionally substituted $-(CR^b{}_2)_n$cycloalkyl. In a further aspect, each R^d is optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl. In another aspect, each R^d is $-C(O)NR^fR^g$.

In an additional aspect, R^e is optionally substituted $-C_1$-C_{12} alkyl. In another aspect, R^e is optionally substituted $-C_2$-C_{12} alkenyl. In a further aspect, R^e is optionally substituted $-C_2$-C_{12} alkynyl. In another aspect, R^e is optionally substituted $-(CR^a{}_2)_n$aryl. In a further aspect, R^e is optionally substituted $-(CR^a{}_2)_n$cycloalkyl. In another aspect, R^e is optionally substituted $-(CR^a{}_2)_n$heterocycloalkyl.

In one aspect, R^f and R^g are each hydrogen. In an additional aspect, R^f and R^g are each optionally substituted $-C_1$-C_{12} alkyl. In another aspect, R^f and R^g are each optionally substituted $-C_2$-C_{12} alkenyl. In an additional aspect, R^f and R^g are each optionally substituted $-C_2$-C_{12} alkynyl. In a further aspect, R^f and R^g are each optionally substituted $-(CR^b{}_2)_n$aryl. In an additional aspect, R^f and R^g are each optionally substituted $-(CR^b{}_2)_n$cycloalkyl. In another aspect, R^f and R^g are each optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl.

In an additional aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup which is O. In another aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup which is NR^c. In another aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup which is S. In one aspect, R^f and R^g may together form an unsubstituted heterocyclic ring, which may contain a second heterogroup. In another aspect, the optionally substituted heterocyclic ring may be substituted with 1 substituent selected from the group consisting of optionally substituted $-C_1$-C_4 alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$. In further aspect, the optionally substituted heterocyclic ring may be substituted with 2 substituents selected from the

group consisting of optionally substituted -C_1-C_4 alkyl, -OR^b, oxo, cyano, -CF_3, optionally substituted phenyl, and -C(O)OR^h. In another aspect, the optionally substituted heterocyclic ring may be substituted with 3 substituents selected from the group consisting of optionally substituted -C_1-C_4 alkyl, -OR^b, oxo, cyano, -CF_3, optionally substituted phenyl, and -C(O)OR^h. In a further aspect, the optionally substituted heterocyclic ring may be substituted with 4 substituents selected from the group consisting of optionally substituted -C_1-C_4 alkyl, -OR^b, oxo, cyano, -CF_3, optionally substituted phenyl, and -C(O)OR^h.

In a further aspect, R^h is optionally substituted -C_1-C_{12} alkyl. In another aspect, R^h is optionally substituted -C_2-C_{12} alkenyl. In a further aspect, R^h is optionally substituted -C_2-C_{12} alkynyl. In another aspect, R^h is optionally substituted -$(CR^b{}_2)_n$aryl. In a further aspect, R^h is optionally substituted -$(CR^b{}_2)_n$cycloalkyl. In another aspect, R^h is optionally substituted -$(CR^b{}_2)_n$heterocycloalkyl.

In one aspect, R^5 is –OH. In another aspect, R^5 is selected from the group consisting of -OH, -OC(O)R^e, -OC(O)OR^h, -F, and -NHC(O)R^e. In a further aspect, R^5 is selected from the group consisting of -OH and -OC(O)R^e. In an additional aspect, R^5 is optionally substituted -OC_1-C_6 alkyl. In another aspect, R^5 is -OC(O)R^e. In a further aspect, R^5 is -OC(O)OR^h. In another aspect, R^5 is –F. In another aspect, R^5 is -NHC(O)R^e. In a further aspect, R^5 is -NHS(=O)R^e. In another aspect, R^5 is -NHS$(=O)_2R^e$. In a further aspect, R^5 is -NHC(=S)NH(R^h). In another aspect, R^5 is -NHC(O)NH(R^h).

In one aspect, R^3 is selected from the group consisting of halogen, optionally substituted -C_1-C_6 alkyl, -CF_3, cyano, -C(O)NR^fR^g, optionally substituted $(CR^a2)_n$aryl, -$SO_2NR^fR^g$, and -SO_2R^e. In another aspect, R^3 is *iso*-propyl. In a further aspect, R^3 is alkyl of 1 to 4 carbons or cycloalkyl of 3 to 7 carbons. In yet another aspect, R^3 is selected from the group consisting of halogen, optionally substituted -C_1-C_6 alkyl, optionally substituted -CH_2aryl, optionally substituted -CH(OH)aryl, -C(O)-amido, -S$(=O)_2$-amido, wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methylpiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and -SO_2R^e wherein R^e is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl. In another aspect, R^3 is iodo. In yet another aspect, R^3 is selected from the group consisting of iodo, bromo, optionally substituted -C_1-C_6 alkyl, optionally substituted -CH_2aryl, optionally substituted -CH(OH)aryl, -C(O)-amido, -S$(=O)_2$-amido, wherein the amido group is

selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and $-SO_2R^e$ wherein R^e is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl. In one aspect, R^3 is -CH(OH)(4-fluorophenyl).

In one aspect, X is $-P(O)YR^{11}Y'R^{11}$.

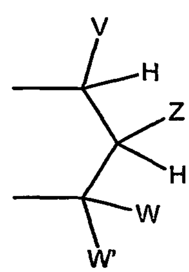
In one aspect, X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z_2OC(O)R^y]_2$, $-P(O)[-OCR^z_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y][-OR^{11}]$, and $-P(O)[-OCH(V)CH_2CH_2O-]$, wherein V is selected from the group consisting of optionally substituted aryl, aryl, heteroaryl, and optionally substituted heteroaryl. In another aspect, is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z_2OC(O)R^y]_2$, $-P(O)[-OCR^z_2OC(O)OR^y]_2$, $-P(O)[-OCH_2CH_2SC(O)Me]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y][-OR^{11}]$ and $-P(O)[-OCH(V)CH_2CH_2O-]$, wherein V is selected from the group consisting of optionally substituted aryl, aryl, heteroaryl, and optionally substituted heteroaryl. In another aspect, X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z_2OC(O)R^y]_2$, $-P(O)[-OCR^z_2OC(O)OR^y]_2$, $-P(O)[-Oalk-SC(O)R^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y][-OR^{11}]$ and $-P(O)[-OCH(V)CH_2CH_2O-]$, wherein V is selected from the group consisting of optionally substituted aryl, aryl, heteroaryl, and optionally substituted heteroaryl. In one aspect, X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCH_2OC(O)$-*t*-butyl$]_2$, $-P(O)[-OCH_2OC(O)O$-*i*-propyl$]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], $-P(O)[-O-CH_2CH_2S-C(O)CH_3]_2$, and $-P(O)[-OCH(3\text{-chlorophenyl})CH_2CH_2O-]$. In a further aspect, X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCH_2OC(O)$-*t*-butyl$]_2$, $-P(O)[-OCH_2OC(O)O$-*i*-propyl$]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$[3,4-methylenedioxy-phenyl], $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], and $-P(O)[-OCH(3\text{-chlorophenyl})CH_2CH_2O-]$. In another aspect, X is $-PO_3H_2$. In yet

another aspect, X is selected from the group consisting of -P(O)[-OCH_2OC(O)-*t*-butyl]$_2$ and -P(O)[-OCH_2OC(O)-*i*-propyl]$_2$.

In one aspect, X is selected from the group consisting of -P(O)[-OCH_2OC(O)O-ethyl]$_2$ and -P(O)[-OCH_2OC(O)O-*i*-propyl]$_2$. In another aspect, X is selected from the group consisting of -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$_2$ and -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3]$_2$. In a further aspect, X is -P(O)[-OCH_2CH_2SC(O)Me]$_2$. In another aspect, X is selected from the group consisting of -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3][3,4-methylenedioxyphenyl] and -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3][3,4-methylenedioxyphenyl]. In a further aspect, X is selected from the group consisting of -PO_3H_2, -P(O)[-$OCR^z_2OC(O)R^y$]$_2$, -P(O)[-$OCR^z_2OC(O)OR^y$]$_2$, -P(O)[-N(H)$CR^z_2C(O)OR^y$]$_2$, -P(O)[-N(H)$CR^z_2C(O)OR^y$][-OR^{11}] and -P(O)[-OCH(V)CH_2CH_2O-], wherein V is selected from the group consisting of optionally substituted aryl, aryl, heteroaryl, and optionally substituted heteroaryl. In another aspect, X is selected from the group consisting of -PO_3H_2, -P(O)[-OCH_2OC(O)-*t*-butyl]$_2$, -P(O)[-OCH_2OC(O)O-*i*-propyl]$_2$, -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$_2$, -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3]$_2$, -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3][3,4-methylenedioxyphenyl], -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3][3,4-methylenedioxyphenyl], and -P(O)[-OCH(3-chlorophenyl)CH_2CH_2O-].

In another aspect, X is -P(O)$YR^{11}Y'R^{11}$

wherein Y and Y' are each independently selected from -O- and -NR^v-; together R^{11} and R^{11} are the group:



,

wherein

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy, alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, that is fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0–2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of $-CHR^zOH$, $-CHR^zOC(O)R^y$, $-CHR^zOC(S)R^y$, $-CHR^zOC(S)OR^y$, $-CHR^zOC(O)SR^y$, $-CHR^zOCO_2R^y$, $-OR^z$, $-SR^z$, $-CHR^zN_3$, $-CH_2aryl$, $-CH(aryl)OH$, $-CH(CH{=}CR^z_2)OH$, $-CH(C{\equiv}CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2NHaryl$, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

with the provisos that:

a) V, Z, W, W' are not all -H; and

b) when Z is $-R^z$, then at least one of V, W, and W' is not -H, alkyl, aralkyl, or heterocycloalkyl;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl; and

Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl.

In one aspect, V is optionally substituted aryl. In another aspect, V is selected from the group consisting of 3-chlorophenyl, 4-chlorophenyl, 3-bromophenyl, 3-fluorophenyl, pyrid-4-yl, pyrid-3-yl and 3,5-dichlorophenyl.

In one aspect, the relative stereochemistry between the V-group substituent and T on the dioxaphosphonane ring is *cis*. In another aspect, the *cis* dioxaphosphonane ring has *R* stereochemistry at the carbon where V is attached. In another aspect, the *cis* dioxaphosphonane ring has *S* stereochemistry at the carbon where V is attached.

In one aspect R^{11} is not hydrogen.

In a further aspect when G is -O-, T is $-CH_2-$, R^1 and R^2 are each bromo, R^3 is *iso*-propyl, and R^5 is -OH, then R^4 is not hydrogen. In another aspect, when G is -O-, T is $-(CH_2)_{0-4}-$, R^1 and R^2 are independently selected from the group consisting of halogen, alkyl of 1 to 3 carbons, and cycloalkyl of 3 to 5 carbons, R^3 is alkyl of 1 to 4 carbons or cycloalkyl of 3 to 7 carbons, and R^5 is -OH, then R^4 is not hydrogen; and wherein when G is -O-, R^5 is selected from the group consisting of $NHC(O)R^e$, $-NHS(=O)_{1-2}R^e$, $-NHC(=S)NH(R^h)$, and $-NHC(O)NH(R^h)$, T is selected from the group consisting of $-(CH_2)_m-$, -CH=CH-, $-O(CH_2)_{1-2}-$, and $-NH(CH_2)_{1-2}-$, then R^4 is not hydrogen.In a further aspect for the compounds of Formula I, G is selected from the group consisting of -O- and $-CH_2-$; T is selected from the group consisting of $-(CR^a_2)_n$, $-O(CR^b_2)(CR^a_2)_p-$, $-N(R^c)(CR^b_2)(CR^a_2)_p-$, $-S(CR^b_2)(CR^a_2)_p-$, $-NR^b(CO)-$, and $-CH_2CH(NR^cR^b)-$; R^1 and R^2 are each independently selected from the group consisting of halogen, $-C_1-C_4$ alkyl, $-CF_3$, and cyano; R^4 is selected from the group consisting of hydrogen, halogen, $-C_1-C_4$ alkyl, cyano and CF_3; R^5 is selected from the group consisting of -OH, $-OC(O)R^e$, $-OC(O)OR^h$, -F and $-NHC(O)R^e$; R^3 is selected from the group consisting of halogen, optionally substituted $-C_1-C_6$ alkyl, $-CF_3$, cyano, $-C(O)NR^fR^g$, optionally substituted $-(CR^a_2)_n$aryl, $-SO_2NR^fR^g$, and $-SO_2R^e$; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z_2OC(O)R^y]_2$, $-P(O)[-OCR^z_2OC(O)OR^y]_2$, $-P(O)[-Oalk-SC(O)R^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y][-OR^{11}]$ and $-P(O)[-OCH(V)CH_2CH_2O-]$, wherein V is selected from the group consisting of optionally substituted aryl, aryl, heteroaryl, and optionally substituted heteroaryl.

In another aspect, G is selected from the group consisting of -O- and $-CH_2-$; T is selected from the group consisting of

$-(CR^a{}_2)_n$, $-O(CR^b{}_2)(CR^a{}_2)_p-$, $-N(R^c)(CR^b{}_2)(CR^a{}_2)_p-$, $-S(CR^b{}_2)(CR^a{}_2)_p-$, $-NR^b(CO)-$, and $-CH_2CH(NR^cR^b)-$; R^1 and R^2 are each independently selected from the group consisting of halogen, $-C_1-C_4$ alkyl, $-CF_3$, and cyano; R^4 is selected from the group consisting of hydrogen, halogen, $-C_1-C_4$ alkyl, cyano and CF_3; R^5 is selected from the group consisting of -OH, $-OC(O)R^e$, $-OC(O)OR^h$, -F and $-NHC(O)R^e$; R^3 is selected from the group consisting of halogen, optionally substituted $-C_1-C_6$ alkyl, $-CF_3$, cyano, $-C(O)NR^fR^g$, optionally substituted $-(CR^a{}_2)_n$aryl, $-SO_2NR^fR^g$, and $-SO_2R^e$; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z{}_2OC(O)R^y]_2$, $-P(O)[-OCR^z{}_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y][-OR^{11}]$ and $-P(O)[-OCH(V)CH_2CH_2O-]$, wherein V is selected from the group consisting of optionally substituted aryl, aryl, heteroaryl, and optionally substituted heteroaryl.

In an additional aspect, G is selected from the group consisting of -O- and $-CH_2-$; T is $-CH_2CH(NH_2)-$; R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano; R^4 is hydrogen; R^5 is selected from the group consisting of –OH and $-OC(O)R^e$; R^3 is selected from the group consisting of halogen, optionally substituted $-C_1-C_6$ alkyl, optionally substituted $-CH_2$aryl, optionally substituted -CH(OH)aryl, -C(O)-amido wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, $-S(=O)_2$-amido wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and $-SO_2R$ wherein R is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl, and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z{}_2OC(O)R^y]_2$, $-P(O)[-OCR^z{}_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y][OR^e]$ and $-P(O)[-OCR^z(aryl)CH_2CH_2O-]$.

In another aspect, when G is -O-, T is $-CH_2-$, R^1 and R^2 are bromo, R^3 is *iso*-propyl, R^5 is -OH, and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z{}_2OC(O)R^y]_2$, $-P(O)[-OCR^z{}_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y][OR^e]$ and $-P(O)[-OCR^z(aryl)CH_2CH_2O-]$, then R^4 is not hydrogen.

In one aspect for the compounds of Formula I, G is -O-; T is $-CH_2CH(NH_2)-$; R^1 and R^2 are each iodo; R^4 is selected from the group consisting of hydrogen and iodo; R^5 is -OH; and R^3 is iodo; and X is selected from the group consisting of $-PO_3H_2$,

-P(O) [-OCR$^z_2$OC(O)R^y]$_2$, -P(O)[-OCR$^z_2$OC(O)OR^y]$_2$, -P(O)[-N(H)CR$^z_2$C(O)OR^y]$_2$, -P(O)[-N(H)CR$^z_2$C(O)OR^y][OR^e] and -P(O)[-OCR^z(aryl)CH$_2$CH$_2$O-].

In another aspect G is -O-; T is -CH$_2$CH(NH$_2$)-; R^1 and R^2 are each iodo; R^4 is selected from the group consisting of hydrogen and iodo; R^5 is -OH; R^3 is iodo; and X is selected from the group consisting of -PO$_3$H$_2$, -P(O)[-OCH$_2$OC(O)-*t*-butyl]$_2$, -P(O) [-OCH$_2$OC(O)O-*i*-propyl]$_2$, -P(O)[-N(H)CH(CH$_3$)C(O)OCH$_2$CH$_3$]$_2$, -P(O)[-N(H)C(CH$_3$)$_2$C(O)OCH$_2$CH$_3$]$_2$, -P(O)[-N(H)CH(CH$_3$)C(O)OCH$_2$CH$_3$][3,4-methylenedioxyphenyl], -P (O)[-N(H)C(CH$_3$)$_2$C(O)OCH$_2$CH$_3$][3,4-methylenedioxyphenyl], and -P(O)[-OCH(3-chlorophenyl)CH$_2$CH$_2$O-].

In a further aspect for compounds of Formula I, G is selected from the group consisting of -O- and -CH$_2$-; T is -N(H)C(O)-; R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano; R^4 is selected from the group consisting of hydrogen, iodo, 4-chlorophenyl, and cyclohexyl; R^5 is selected from the group consisting of –OH and -OC(O)R^e; R^3 is selected from the group consisting of hydrogen, iodo, bromo, optionally substituted -C$_1$-C$_6$ alkyl, optionally substituted -CH$_2$aryl, optionally substituted -CH(OH)aryl, -C(O)-amido wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, -S(=O)$_2$-amido wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and -SO$_2$R wherein R is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl; and X is selected from the group consisting of -PO$_3$H$_2$, -P(O)[-OCR$^z_2$OC(O)R^y]$_2$, -P(O)[-OCR$^z_2$OC(O)OR^y]$_2$, -P(O)[-N(H)CR$^z_2$C(O)OR^y]$_2$, -P(O)[-N(H)CR$^z_2$C(O)OR^y][OR^e] and -P(O)[-OCR^z(aryl)CH$_2$CH$_2$O-].

An additional aspect is when G is -O-; T is -N(H)C(O)-; R^1 and R^2 are methyl; R^4 is hydrogen; R^5 is -OH; R^3 is -CH(OH)(4-fluorophenyl); and X is selected from the group consisting of -PO$_3$H$_2$, -P(O)[-OCR$^z_2$OC(O)R^y]$_2$, -P(O) [-OCR$^z_2$OC(O)OR^y]$_2$, -P(O)[-N(H)CR$^z_2$C(O)OR^y]$_2$, -P(O)[-N(H)CR$^z_2$C(O)OR^y][OR^e] and -P(O)[-OCR^z(aryl)CH$_2$CH$_2$O-].

In an additional aspect, G is -O-; T is -N(H)C(O)-; R^1 and R^2 are each methyl; R^4 is hydrogen; R^5 is -OH; R^3 is -CH(OH)(4-fluorophenyl); and X is selected from the

group consisting of $-PO_3H_2$, $-P(O)[-OCH_2OC(O)$-*t*-butyl$]_2$, $-P(O)[-OCH_2OC$ $(O)O$-*i*-propyl$]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], and $-P(O)[-OCH$(3-chlorophenyl)$CH_2CH_2O-]$.

In a further aspect G is selected from the group consisting of -O- and $-CH_2-$; T is $-OCH_2-$; R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano; R^4 is selected from the group consisting of hydrogen, iodo, 4-chlorophenyl, and cyclohexyl; R^5 is selected from the group consisting of –OH and $-OC(O)R^e$; R^3 is selected from the group consisting of hydrogen, iodo, bromo, optionally substituted lower alkyl, optionally substituted $-CH_2$aryl, optionally substituted -CH(OH)aryl, -C(O)-amido wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, $-S(=O)_2$-amido wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and $-SO_2R$ wherein R is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z{}_2OC(O)R^y]_2$, $-P(O)[-OCR^z{}_2OC(O)OR^y]_2$, $P(O)[-N(H)CR^z{}_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y][OR^e]$ and $-P(O)[-OCR^z(aryl)CH_2CH_2O-]$.

In another aspect G is $-CH_2-$; T is $-OCH_2-$; R^1 and R^2 are each methyl; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z{}_2OC(O)R^y]_2$, $-P(O)[-OCR^z{}_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y][OR^e]$ and $-P(O)[-OCR^z(aryl)CH_2CH_2O-]$.

In another aspect, G is $-CH_2-$; T is $-OCH_2-$; R^1 and R^2 are each methyl; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCH_2OC(O)$-*t*-butyl$]_2$, $-P(O)[-OCH_2OC(O)O$-*i*-propyl$]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], and $-P(O)[-OCH$(3-chlorophenyl)$CH_2CH_2O-]$.

In a further aspect, G is selected from the group consisting of -O- and $-CH_2-$; T is $-CH_2-$; R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano; R^4 is selected from the group consisting of hydrogen, iodo, 4-chlorophenyl, and cyclohexyl; R^5 is selected from the group consisting of –OH and $-OC(O)R^e$; R^3 is selected from the group consisting of hydrogen, iodo, bromo, optionally substituted lower alkyl, optionally substituted $-CH_2$aryl, optionally substituted -CH(OH)aryl, -C(O)-amido wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, $-S(=O)_2$-amido wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl,and-SO_2R wherein R is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl.; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z{}_2OC(O)R^y]_2$, $-P(O)[-OCR^z{}_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y][OR^e]$ and $-P(O)[-OCR^z(aryl)CH_2CH_2O-]$.

In additional aspects, when G is -O-, T is $-CH_2-$, R^1 and R^2 are each bromo, R^3 is *iso*-propyl, R^5 is –OH; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z{}_2OC(O)R^y]_2$, $-P(O)[-OCR^z{}_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y][OR^e]$ and $-P(O)[-OCR^z(aryl)CH_2CH_2O-]$, then R^4 is not hydrogen.

In another aspect, G is -O-; T is $-CH_2-$; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is -OH; R^3 is *i*-propyl; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z{}_2OC(O)R^y]_2$, $-P(O)[-OCR^z{}_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y][OR^e]$ and $-P(O)[-OCR^z(aryl)CH_2CH_2O-]$.

In another aspect, G is -O-; T is $-CH_2-$; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is -OH; R^3 is *i*-propyl; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCH_2OC(O)$-*t*-butyl$]_2$, $-P(O)[-OCH_2OC(O)O$-*i*-propyl$]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], and $-P(O)[-OCH$(3-chlorophenyl)$CH_2CH_2O-]$.

In additional aspects for compounds of Formula I, G is selected from the group consisting of -O- and $-CH_2-$; T is $-CH_2CH_2-$; R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano; R^4 is selected from the group consisting of hydrogen, iodo, 4-chlorophenyl, and cyclohexyl; R^5 is selected from the group consisting of –OH and $-OC(O)R^e$; R^3 is selected from the group consisting of hydrogen, iodo, bromo, optionally substituted lower alkyl, optionally substituted $-CH_2$aryl, optionally substituted -CH(OH)aryl, -C(O)-amido wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, $-S(=O)_2$-amido wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and $-SO_2R$ wherein R is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z_2OC(O)R^y]_2$, $-P(O)[-OCR^z_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y][OR^e]$ and $-P(O)[-OCR^z(aryl)CH_2CH_2O-]$.

In a further aspect, G is -O-; T is $-CH_2CH_2-$; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z_2OC(O)R^y]_2$, $-P(O)[-OCR^z_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y][OR^e]$ and $-P(O)[-OCR^z(aryl)CH_2CH_2O-]$.

In another aspect, G is -O-; T is $-CH_2CH_2-$; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCH_2OC(O)$-*t*-butyl$]_2$, $-P(O)[-OCH_2OC(O)O$-*i*-propyl$]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$, $--P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], and $-P(O)[-OCH(3\text{-chlorophenyl})CH_2CH_2O-]$.

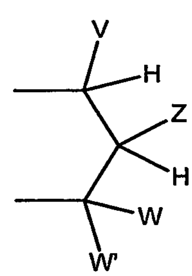
In an additional aspect, G is $-CH_2-$; T is $-OCH_2-$; R^1 and R^2 are each methyl; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and X is $-PO_3H_2$. In a further aspect, G is $-CH_2-$; T is $-OCH_2-$; R^1 and R^2 are each methyl; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and X is selected from the group consisting of $-P(O)[-OCH_2OC(O)$-*t*-butyl$]_2$ and $-P(O)[-OCH_2OC(O)$-*i*-propyl$]_2$. In another aspect, G is $-CH_2-$; T is $-OCH_2-$; R^1 and R^2 are each methyl; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and X is selected from

the group consisting of -P(O)[-OCH_2OC(O)O-ethyl]$_2$ and -P(O)[-OCH_2OC(O)O-*i*-propyl]$_2$. In an additional aspect, G is -CH_2-; T is -OCH_2-; R^1 and R^2 are each methyl; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and X is selected from the group consisting of -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$_2$ and -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3]$_2$. In additional aspects, G is -CH_2-; T is -OCH_2-; R^1 and R^2 are methyl; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and X is -P(O)[-OCH_2CH_2SC(O)Me]$_2$, or X is -P(O)[-N(H)C(CH_3)C(O)OCH_2CH_3][3,4-methylenedioxyphenyl], or X is -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3][3,4-methylenedioxyphenyl].

In another aspect, G is -O-, T is -(CH_2)$_{0-4}$-, R^1 and R^2 are independently selected from the group consisting of hydrogen, halogen, alkyl of 1 to 3 carbons, and cycloalkyl of 3 to 5 carbons, R^3 is alkyl of 1 to 4 carbons or cycloalkyl of 3 to 7 carbons, and R^5 is -OH, then R^4 is not hydrogen; and wherein when G is -O-, R^5 is selected from the group consisting of NHC(O)R^e, -NHS(=O)$_{1-2}R^e$, -NHC(S)NH(R^h), and -NHC(O)NH(R^h), T is selected from the group consisting of -(CH_2)$_m$-, -CH=CH-, -O(CH_2)$_{1-2}$-, and -NH(CH_2)$_{1-2}$-, then R^4 is not hydrogen.

In an additional aspect, G is -CH_2-; T is -OCH_2-; R^1 and R^2 are each methyl; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and X is -P(O)YR^{11}Y'R^{11};

wherein Y and Y' are each independently selected from -O- and -NR^v-; together R^{11} and R^{11} are the group:



wherein:

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0 - 1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkoxycarbonyloxy, or

aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0 - 1 atoms are heteroatoms and the remaining atoms are carbon, that is fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0 - 1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0 - 2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of $-CHR^zOH$, $-CHR^zOC(O)R^y$, $-CHR^zOC(S)R^y$, $-CHR^zOC(S)OR^y$, $-CHR^zOC(O)SR^y$, $-CHR^zOCO_2R^y$, $-OR^z$, $-SR^z$, $-CHR^zN_3$, $-CH_2aryl$, -CH(aryl)OH, $-CH(CH{=}CR^z_2)OH$, $-CH(C{\equiv}CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2NHaryl$, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

with the provisos that:

a) V, Z, W, W' are not all -H; and

b) when Z is $-R^z$, then at least one of V, W, and W' is not -H, alkyl, aralkyl, or heterocycloalkyl;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl;

Each R^x is independently selected from the group consisting of -H, and alkyl, or together R^x and R^x form a cyclic alkyl group;

Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl. In a further aspect V is aryl. In an additional

aspect Z is hydrogen, W is hydrogen, and W' is hydrogen. In an additional aspect, V is 3-chlorophenyl, 4-chlorophenyl, 3-bromophenyl, 3-fluorophenyl, pyrid-4-yl, pyrid-3-yl or 3,5-dichlorophenyl. In a further aspect the relative stereochemistry between the substituents on the dioxaphosphonane ring is *cis*.

In another aspect, each R^a is independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_2 alkyl, halogen, -OH, optionally substituted -O-C_1-C_2 alkyl, -OCF_3, optionally substituted -S-C_1-C_2 alkyl, -NR^bR^c, optionally substituted -C_2 alkenyl, and optionally substituted -C_2 alkynyl;

Each R^b is independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_2 alkyl;

Each R^c is independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_4 alkyl, and optionally substituted -C(O)-C_1-C_2 alkyl, -C(O)H;

Each R^d is selected from the group consisting of optionally substituted -C_1-C_6 alkyl, optionally substituted -C_2-C_6 alkenyl, optionally substituted -C_2-C_6 alkynyl, optionally substituted -$(CR^b{}_2)_n$phenyl, optionally substituted -$(CR^b{}_2)_n$monocyclic-heteroaryl, optionally substituted -$(CR^b{}_2)_n$-C_3-C_6-cycloalkyl, optionally substituted -$(CR^b{}_2)_n$-C_4-C_5-heterocycloalkyl, and -C(O)NR^fR^g;

Each R^e is selected from the group consisting of optionally substituted -C_1-C_6 alkyl, optionally substituted -C_2-C_6 alkenyl, optionally substituted -C_2-C_6 alkynyl, optionally substituted -$(CR^b{}_2)_n$phenyl, optionally substituted -$(CR^b{}_2)_n$monocyclic-heteroaryl, optionally substituted -$(CR^b{}_2)_n$-C_3-C_6-cycloalkyl, optionally substituted -$(CR^b{}_2)_n$-C_4-C_5-heterocycloalkyl;

R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_6 alkyl, optionally substituted -C_2-C_6 alkenyl, optionally substituted -C_2-C_6 alkynyl, optionally substituted -$(CR^b{}_2)_n$phenyl, optionally substituted -$(CR^b{}_2)_n$monocyclic-heteroaryl, optionally substituted -$(CR^b{}_2)_n$-C_3-C_6-cycloalkyl, optionally substituted -$(CR^b{}_2)_n$-C_4-C_5-heterocycloalkyl, or R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup selected from the group of O, NR^b, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-2 substituents selected from the group consisting of optionally substituted -C_1-C_2 alkyl, -OR^b, oxo, cyano, -CF_3, optionally substituted phenyl, and -C(O)OR^h;

Each R^h is optionally substituted -C_1-C_{16} alkyl, optionally substituted -C_2-C_{16} alkenyl, optionally substituted -C_2-C_{16} alkynyl, optionally substituted -$(CR^b{}_2)_n$phenyl, optionally substituted -$(CR^b{}_2)_n$monocyclic-heteroaryl, optionally substituted -$(CR^b{}_2)_n$-C_3-C_6-cycloalkyl, optionally substituted -$(CR^b{}_2)_n$-C_4-C_5-heterocycloalkyl.

In a further aspect, each R^a is independently selected from the group consisting of hydrogen, methyl, fluoro, chloro, -OH, -O-CH_3, -OCF_3, -SCH_3, -$NHCH_3$, -$N(CH_3)_2$;

Each R^b is independently selected from the group consisting of hydrogen, and methyl;

Each R^c is independently selected from the group consisting of hydrogen, methyl, -C(O)CH_3, -C(O)H;

Each R^d is selected from the group consisting of optionally substituted -C_1-C_4 alkyl, optionally substituted -C_2-C_4 alkenyl, optionally substituted -C_2-C_4 alkynyl, optionally substituted -$(CH_2)_n$phenyl, optionally substituted -$(CH_2)_n$monocyclic-heteroaryl, optionally substituted -$(CH_2)_n$-C_3-C_6-cycloalkyl, optionally substituted -$(CH_2)_n$-C_4-C_5-heterocycloalkyl, and -C(O)NR^fR^g;

Each R^e is selected from the group consisting of optionally substituted -C_1-C_4 alkyl, optionally substituted -C_2-C_4 alkenyl, optionally substituted -C_2-C_4 alkynyl, optionally substituted -$(CH_2)_n$phenyl, optionally substituted -$(CH_2)_n$monocyclic-heteroaryl, optionally substituted -$(CH_2)_n$-C_3-C_6-cycloalkyl, optionally substituted -$(CH_2)_n$-C_4-C_5-heterocycloalkyl;

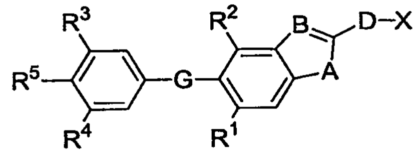
R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_4 alkyl, optionally substituted -C_2-C_4 alkenyl, optionally substituted -C_2-C_4 alkynyl, optionally substituted -$(CH_2)_n$phenyl, optionally substituted -$(CH_2)_n$monocyclic-heteroaryl, optionally substituted -$(CH_2)_n$-C_3-C_6-cycloalkyl, optionally substituted -$(CH_2)_n$-C_4-C_5-heterocycloalkyl, or R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup selected from the group of O, NR^b, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-2 substituents selected from the group consisting of optionally substituted methyl, -OR^b, oxo, cyano, -CF_3, optionally substituted phenyl, and -C(O)OR^h;

Each R^h is optionally substituted -C_1-C_4 alkyl, optionally substituted -C_2-C_4 alkenyl, optionally substituted -C_2-C_4 alkynyl, optionally substituted -$(CH_2)_n$phenyl, optionally substituted -$(CH_2)_n$monocyclic-heteroaryl,

optionally substituted $-(CH_2)_n-C_3-C_6$-cycloalkyl, optionally substituted $-(CH_2)_n-C_4-C_5$-heterocycloalkyl.

Each of the individual species of compounds of Formula I which can be generated by making all of the above permutations may be specifically set forth as for inclusion or may be specifically excluded from the present invention.

In another aspect, the invention relates to compounds of Formula II, stereoisomers, pharmaceutically acceptable salts and prodrugs thereof and pharmaceutically acceptable salts of the prodrugs as represented by Formula II:



wherein:

A is selected from the group consisting of $-NR^i-$, -O-, and -S-;

B is selected from the group consisting of $-CR^b-$, and -N-;

R^i is selected from the group consisting of hydrogen, $-C(O)C_1-C_4$ alkyl, $-C_1-C_4$ alkyl, and $-C_1-C_4$-aryl;

R^b is selected from the group consisting of hydrogen and optionally substituted $-C_1-C_4$ alkyl;

G is selected from the group consisting of -O-, -S-, -S(=O)-, $-S(=O)_2-$, $-CH_2-$, $-CF_2-$, -CHF-, -C(O)-, -CH(OH)-, -NH-, and $-N(C_1-C_4$ alkyl)-;

D is selected from the group consisting of a bond, $-(CR^a_2)$ -, and -C(O)-;

Each R^a is independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_4$ alkyl, halogen, -OH, optionally substituted $-O-C_1-C_4$ alkyl, $-OCF_3$, optionally substituted $-S-C_1-C_4$ alkyl, $-NR^bR^c$, optionally substituted $-C_2-C_4$ alkenyl, and optionally substituted $-C_2-C_4$ alkynyl; with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom;

R^1 and R^2 are each independently selected from the group consisting of halogen, optionally substituted $-C_1-C_4$ alkyl, optionally substituted $-S-C_1-C_3$ alkyl, optionally substituted $-C_2-C_4$ alkenyl, optionally substituted $-C_2-C_4$ alkynyl, $-CF_3$, $-OCF_3$, optionally substituted$-O-C_1-C_3$ alkyl, and cyano;

R^3 and R^4 are each independently selected from the group consisting of hydrogen, halogen, $-CF_3$, $-OCF_3$, cyano, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a{}_2)_m$aryl, optionally substituted $-(CR^a{}_2)_m$cycloalkyl, optionally substituted $-(CR^a{}_2)_m$heterocycloalkyl, $-OR^d$, $-SR^d$, $-S(=O)R^e$, $-S(=O)_2R^e$, $-S(=O)_2NR^fR^g$, $-C(O)NR^fR^g$, $-C(O)OR^h$, $-C(O)R^e$, $-N(R^b)C(O)R^e$, $-N(R^b)C(O)NR^fR^g$, $-N(R^b)S(=O)_2R^e$, $-N(R^b)S(=O)_2NR^fR^g$, and $-NR^fR^g$;

Each R^d is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl, and $-C(O)NR^fR^g$;

Each R^e is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a{}_2)_n$aryl, optionally substituted $-(CR^a{}_2)_n$cycloalkyl, and optionally substituted $-(CR^a{}_2)_n$heterocycloalkyl;

R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, and optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl, or R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup selected from the group consisting of O, NR^c, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-4 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$;

Each R^h is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, and optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl;

R^5 is selected from the group consisting of -OH, optionally substituted $-OC_1-C_6$ alkyl, $-OC(O)R^e$, $-OC(O)OR^h$, -F, $-NHC(O)R^e$, $-NHS(=O)R^e$, $-NHS(=O)_2R^e$, $-NHC(=S)NH(R^h)$, and $-NHC(O)NH(R^h)$;

X is $P(O)YR^{11}Y'R^{11}$;

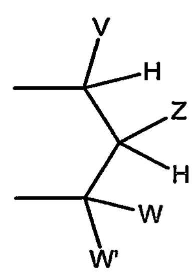
Y and Y' are each independently selected from the group consisting of -O-, and $-NR^v-$; when Y and Y' are -O- , R^{11} attached to -O- is independently selected from

the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, $-C(R^z)_2OC(O)NR^z_2$, $-NR^z-C(O)-R^y$, $-C(R^z)_2-OC(O)R^y$, $-C(R^z)_2-O-C(O)OR^y$, $-C(R^z)_2OC(O)SR^y$, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy;

when Y and Y' are $-NR^v-$, then R^{11} attached to $-NR^v-$ is independently selected from the group consisting of -H, $-[C(R^z)_2]_q-COOR^y$, $-C(R^x)_2COOR^y$, $-[C(R^z)_2]_q-C(O)SR^y$, and -cycloalkylene-$COOR^y$;

when Y is -O- and Y' is NR^v, then R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, $-C(R^z)_2OC(O)NR^z_2$, $-NR^z-C(O)-R^y$, $-C(R^z)_2-OC(O)R^y$, $-C(R^z)_2-O-C(O)OR^y$, $-C(R^z)_2OC(O)SR^y$, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy; and R^{11} attached to $-NR^v-$ is independently selected from the group consisting of -H, $-[C(R^z)_2]_q-COOR^y$, $-C(R^x)_2COOR^y$, $-[C(R^z)_2]_q-C(O)SR^y$, and -cycloalkylene-$COOR^y$;

or when Y and Y' are independently selected from -O- and $-NR^v-$, then together R^{11} and R^{11} are -alkyl-S-S-alkyl- to form a cyclic group, or together R^{11} and R^{11} are the group:



wherein:

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy, alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, that is fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0–2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of $-CHR^zOH$, $-CHR^zOC(O)R^y$, $-CHR^zOC(S)R^y$, $-CHR^zOC(S)OR^y$, $-CHR^zOC(O)SR^y$, $-CHR^zOCO_2R^y$, $-OR^z$, $-SR^z$, $-CHR^zN_3$, $-CH_2aryl$, -CH(aryl)OH, $-CH(CH{=}CR^z_2)OH$, $-CH(C{\equiv}CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2NHaryl$, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl;

Each R^x is independently selected from the group consisting of -H, and alkyl, or together R^x and R^x form a cyclic alkyl group;

Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl;

with the provisos that:

a) V, Z, W, W' are not all -H; and

b) when Z is $-R^z$, then at least one of V, W, and W' is not -H, alkyl, aralkyl, or heterocycloalkyl.

In another aspect, G is selected from the group consisting of -O- and $-CH_2-$. In one aspect, G is -O-. In another aspect, G is -S-. In another aspect, G is -S(=O)-. In a further aspect, G is $-S(=O)_2-$. In another aspect, G is $-CH_2-$. In a further aspect, G is $-CF_2-$. In another aspect, G is -CHF-. In a further aspect, G is -C(O)-. In another aspect, G is -CH(OH)-. In another aspect, G is -NH-. In a further aspect, G is $-N(C_1-C_4$ alkyl)-.

In a further aspect, D is selected from the group consisting of a bond and $-CH_2-$. In another aspect D is a bond. In a further aspect D is $-(CR^a_2)$ -. In another aspect D is -C(O)-.

In yet another aspect A is selected from -NH-, -NMe-, -O-, and -S-. In one aspect, A is $-NR^i-$. In another aspect, A is -O-. In a further aspect, A is -S-.

In a further aspect, B is selected from $-CH_2-$, CMe-, and -N-. In another aspect, B is $-CR^b-$. In a further aspect, B is -N-.

In one aspect, R^i is hydrogen, $-C(O)C_1-C_4$ alkyl. In another aspect, R^i is $-C_1-C_4$ alkyl. In a further aspect, R^i is $-C_1-C_4$-aryl.

In one aspect, R^b is hydrogen. In another aspect, R^b is optionally substituted $-C_1-C_4$ alkyl.

In another aspect, R^a is hydrogen with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, R^a is optionally substituted $-C_1-C_4$ alkyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, R^a is halogen with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, R^a is –OH with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, R^a is optionally substituted $-O-C_1-C_4$ alkyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, R^a is $-OCF_3$ with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a

hydrogen, or attached via a carbon atom. In a further aspect, R^a is optionally substituted -S-C_1-C_4 alkyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, R^a is -NR^bR^c with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In further aspect, R^a is optionally substituted -C_2-C_4 alkenyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, R^a is optionally substituted -C_2-C_4 alkynyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom.

In one aspect, R^1 and R^2 are the same and are selected from the group consisting of halogen, -C_1-C_4 alkyl, -CF_3, and cyano. In another aspect, R^1 and R^2 are different and are selected from the group consisting of halogen, -C_1-C_4 alkyl, -CF_3, and cyano. In an additional aspect, R^1 and R^2 are each halogen. In another aspect, R^1 and R^2 are each optionally substituted -C_1-C_4 alkyl. In a further aspect, R^1 and R^2 are each optionally substituted -S-C_1-C_3 alkyl. In another aspect, R^1 and R^2 are each optionally substituted -C_2-C_4 alkenyl. In a further aspect, R^1 and R^2 are each optionally substituted -C_2-C_4 alkynyl. In another aspect, R^1 and R^2 are each -CF_3. In a further aspect, R^1 and R^2 are each -OCF_3. In another aspect, R^1 and R^2 are each optionally substituted-O-C_1-C_3 alkyl. In a further aspect, R^1 and R^2 are each cyano.

In yet another aspect, R^3 and R^4 are each hydrogen. In another aspect, R^3 and R^4 are each halogen. In a further aspect, R^3 and R^4 are each -CF_3. In another aspect, R^3 and R^4 are each -OCF_3. In a further aspect, R^3 and R^4 are each cyano. In another aspect, R^3 and R^4 are each optionally substituted -C_1-C_{12} alkyl. In a further aspect, R^3 and R^4 are each optionally substituted -C_2-C_{12} alkenyl. In another aspect, R^3 and R^4 are each optionally substituted -C_2-C_{12} alkynyl. In a further aspect, R^3 and R^4 are each optionally substituted -$(CR^a{}_2)_m$aryl. In another aspect, R^3 and R^4 are each optionally substituted -$(CR^a{}_2)_m$cycloalkyl. In a further aspect, R^3 and R^4 are each optionally substituted -$(CR^a{}_2)_m$heterocycloalkyl. In another aspect, R^3 and R^4 are each -OR^d. In another aspect, R^3 and R^4 are each -SR^d. In a further aspect, R^3 and R^4 are each -S(=O)R^e. In another aspect, R^3 and R^4 are each -$S(=O)_2R^e$. In a further aspect, R^3 and R^4 are each -$S(=O)_2NR^fR^g$. In another aspect, R^3 and R^4 are each -C(O)NR^fR^g. In a further aspect, R^3 and R^4 are each -C(O)OR^h. In another aspect, R^3 and R^4 are

each $-C(O)R^e$. In afurther aspect, R^3 and R^4 are each $-N(R^b)C(O)R^e$. In another aspect, R^3 and R^4 are each $-N(R^b)C(O)NR^fR^g$. In a further aspect, R^3 and R^4 are each $-N(R^b)S(=O)_2R^e$. In another aspect, R^3 and R^4 are each $-N(R^b)S(=O)_2NR^fR^g$. In a further aspect, R^3 and R^4 are each $-NR^fR^g$. In an additional aspect, R^4 is selected from the group consisting of hydrogen, halogen, $-C_1-C_4$ alkyl, cyano and CF_3. In an additional aspect, R^3 is selected from the group consisting of halogen, optionally substituted $-C_1-C_6$ alkyl, $-CF_3$, cyano, $-C(O)NR^fR^g$, optionally substituted $-(CR^a{}_2)_n$aryl, $-SO_2NR^fR^g$, and $-SO_2R^e$.

In another aspect, each R^d is optionally substituted $-C_1-C_{12}$ alkyl. In a further aspect, each R^d is optionally substituted $-C_2-C_{12}$ alkenyl. In another aspect, each R^d is optionally substituted $-C_2-C_{12}$ alkynyl. In a further aspect, each R^d is optionally substituted $-(CR^b{}_2)_n$aryl. In another aspect, each R^d is optionally substituted $-(CR^b{}_2)_n$cycloalkyl. In a further aspect, each R^d is optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl. In another aspect, each R^d is $-C(O)NR^fR^g$.

In an additional aspect, R^e is optionally substituted $-C_1-C_{12}$ alkyl. In another aspect, R^e is optionally substituted $-C_2-C_{12}$ alkenyl. In a further aspect, R^e is optionally substituted $-C_2-C_{12}$ alkynyl. In another aspect, R^e is optionally substituted $-(CR^a{}_2)_n$aryl. In a further aspect, R^e is optionally substituted $-(CR^a{}_2)_n$cycloalkyl. In another aspect, R^e is optionally substituted $-(CR^a{}_2)_n$heterocycloalkyl.

In one aspect, R^f and R^g are each hydrogen. In an additional aspect, R^f and R^g are each optionally substituted $-C_1-C_{12}$ alkyl. In another aspect, R^f and R^g are each optionally substituted $-C_2-C_{12}$ alkenyl. In an additional aspect, R^f and R^g are each optionally substituted $-C_2-C_{12}$ alkynyl. In a further aspect, R^f and R^g are each optionally substituted $-(CR^b{}_2)_n$aryl. In an additional aspect, R^f and R^g are each optionally substituted $-(CR^b{}_2)_n$cycloalkyl. In another aspect, R^f and R^g are each optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl.

In an additional aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup which is O. In another aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup which is NR^c. In another aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup which is S. In one aspect, R^f and R^g may together form an unsubstituted heterocyclic ring, which may contain a second heterogroup. In another aspect, the optionally substituted heterocyclic ring may be substituted with 1 substituent selected

from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$. In further aspect, the optionally substituted heterocyclic ring may be substituted with 2 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$. In another aspect, the optionally substituted heterocyclic ring may be substituted with 3 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$. In a further aspect, the optionally substituted heterocyclic ring may be substituted with 4 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$.

In a further aspect, R^h is optionally substituted $-C_1-C_{12}$ alkyl. In another aspect, R^h is optionally substituted $-C_2-C_{12}$ alkenyl. In a further aspect, R^h is optionally substituted $-C_2-C_{12}$ alkynyl. In another aspect, R^h is optionally substituted $-(CR^b_2)_n$aryl. In a further aspect, R^h is optionally substituted $-(CR^b_2)_n$cycloalkyl. In another aspect, R^h is optionally substituted $-(CR^b_2)_n$heterocycloalkyl.

In another aspect, R^5 is selected from the group consisting of -OH, $-OC(O)R^e$, $-OC(O)OR^h$, -F, and $-NHC(O)R^e$. In an additional aspect, R^5 is optionally substituted $-OC_1-C_6$ alkyl. In another aspect, R^5 is $-OC(O)R^e$. In a further aspect, R^5 is $-OC(O)OR^h$. In another aspect, R^5 is –F. In another aspect, R^5 is $-NHC(O)R^e$. In a further aspect, R^5 is $-NHS(=O)R^e$. In another aspect, R^5 is $-NHS(=O)_2R^e$. In a further aspect, R^5 is
$-NHC(=S)NH(R^h)$. In another aspect, R^5 is $-NHC(O)NH(R^h)$.

In a further aspect, X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z_2OC(O)R^y]_2$, $-P(O)[-OCR^z_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z_2C(O)OR^y][-OR^{11}]$, and $-P(O)[-OCH(V)CH_2CH_2O-]$, wherein V is selected from the group consisting of optionally substituted aryl, aryl, heteroaryl, and optionally substituted heteroaryl.

In one aspect, G is selected from the group consisting of -O- and $-CH_2-$; D is selected from the group consisting of a bond and $-CH_2-$; A is selected from the group consisting of -NH-, -NMe-, -O-, and -S-; B is selected from the group consisting of –CH-, -CMe-, and -N-; R^1 and R^2 are each independently selected from the group consisting of halogen, $-C_1-C_4$ alkyl, $-CF_3$, and cyano; R^4 is selected from the group consisting of hydrogen, halogen, $-C_1-C_4$ alkyl, cyano and CF_3; R^5 is selected from the group consisting

of -OH, $-OC(O)R^e$, $-OC(O)OR^h$, -F, and $-NHC(O)R^e$; R^3 is selected from the group consisting of halogen, optionally substituted $-C_1-C_6$ alkyl, $-CF_3$, cyano, $-C(O)NR^fR^g$, optionally substituted $-(CR^a{}_2)_n$aryl, $-SO_2NR^fR^g$, and $-SO_2R^e$; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z{}_2OC(O)R^y]_2$, $-P(O)[-OCR^z{}_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y][-OR^{11}]$ and $-P(O)[-OCH(V)CH_2CH_2O-]$, wherein V is selected from the group consisting of optionally substituted aryl, aryl, heteroaryl, and optionally substituted heteroaryl. In another aspect, G is selected from the group consisting of -O- and $-CH_2$; D is selected from the group consisting of a bond and $-CH_2-$; A is selected from the group consisting of -NH-, -NMe-, -O-, and -S-; B is selected from the group consisting of –CH-, -CMe- and -N-; R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano; R^4 is selected from the group consisting of hydrogen and halogen; R^5 is selected from the group consisting of -OH and $-OC(O)R^e$; and R^3 is selected from the group consisting of halogen, optionally substituted $-C_1-C_6$ alkyl, optionally substituted $-CH_2$aryl, optionally substituted -CH(OH)aryl, -C(O)-amido, $-S(=O)_2$-amido, wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methylpiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and $-SO_2R^e$ wherein R^e is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl. In yet another aspect, G is -O-; D is a bond; A is selected from the group consisting of -NH- and -NMe-; B is selected from the group consisting of –CH- and -CMe-; R^1 and R^2 are each bromo; R^4 is selected from the group consisting of hydrogen and iodo; R^5 is -OH; and R^3 is isopropyl.

In another aspect, G is -O-; D is a bond; A is selected from the group consisting of -NH- and -NMe-; B is selected from the group consisting of –CH- and -CMe-; R^1 and R^2 are each bromo; R^4 is selected from the group consisting of hydrogen and iodo; R^5 is -OH; R^3 is isopropyl, and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCH_2OC(O)\text{-}t\text{-butyl}]_2$, $-P(O)[-OCH_2OC(O)O\text{-}i\text{-propyl}]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], and $-P(O)[-OCH(3\text{-chlorophenyl})CH_2CH_2O-]$.

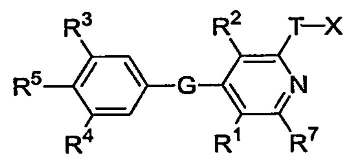
In a further aspect, G is -O-; D is a bond; A is -O-; B is selected from the group consisting of -CH- and -CMe-; R^1 and R^2 are each bromo; R^4 is selected from the group

consisting of hydrogen and iodo; R^5 is -OH; and R^3 is isopropyl. In another aspect, G is -O-; D is a bond; A is -O-; B is selected from the group consisting of -CH- and -CMe-; R^1 and R^2 are each bromo; R^4 is selected from the group consisting of hydrogen and iodo; R^5 is -OH; R^3 is isopropyl, X is selected from the group consisting of $-PO_3H_2$, -P(O)[$-OCH_2OC(O)$-*t*-butyl]$_2$, -P(O)[$-OCH_2OC(O)O$-*i*-propyl]$_2$, -P(O)[$-N(H)CH(CH_3)C(O)OCH_2CH_3$]$_2$, -P(O)[$-N(H)C(CH_3)_2C(O)OCH_2CH_3$]$_2$, -P(O)[$-N(H)CH(CH_3)C(O)OCH_2CH_3$][3,4-methylenedioxyphenyl], -P(O)[$-N(H)C(CH_3)_2C(O)OCH_2CH_3$][3,4-methylenedioxyphenyl], and -P(O)[-OCH(3-chlorophenyl)CH_2CH_2O-].

In an additional aspect, X is $-PO_3H_2$.

Each of the individual species of compounds of Formula II which can be generated by making all of the above permutations may be specifically set forth as for inclusion or may be specifically excluded from the present invention.

In another aspect, the invention relates to compounds of Formula III, stereoisomers, pharmaceutically acceptable salts and prodrugs thereof and pharmaceutically acceptable salts of the prodrugs as represented by Formula III:



wherein:

G is selected from the group consisting of -O-, -S-, -S(=O)-, -S(=O)$_2$-, $-CH_2-$, $-CF_2-$, -CHF-, -C(O)-, -CH(OH)-, -NH-, and -N(C_1-C_4 alkyl)-;

T is selected from the group consisting of $-(CR^a_2)_k-$, $-CR^b=CR^b-(CR^a_2)_n-$, $-(CR^a_2)_n-CR^b=CR^b-$, $-(CR^a_2)-CR^b=CR^b-(CR^a_2)-$, $-O(CR^b_2)(CR^a_2)_n-$, $-S(CR^b_2)(CR^a_2)_n-$, $-N(R^c)(CR^b_2)(CR^a_2)_n-$, $-N(R^b)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nCH(NR^bR^c)-$, $-C(O)(CR^a_2)_m-$, $-(CR^a_2)_mC(O)-$, $-(CR^a_2)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nC(O)(CR^a_2)-$, and $-C(O)NH(CR^b_2)(CR^a_2)_p-$;

k is an integer from 0-4;

m is an integer from 0-3;

n is an integer from 0-2;

p is an integer from 0-1;

Each R^a is independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_4 alkyl, halogen, -OH, optionally substituted -O-C_1-C_4 alkyl, -OCF_3, optionally substituted -S-C_1-C_4 alkyl, -NR^bR^c, optionally substituted -C_2-C_4 alkenyl, and optionally substituted -C_2-C_4 alkynyl; with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom;

Each R^b is independently selected from the group consisting of hydrogen and optionally substituted -C_1-C_4 alkyl;

Each R^c is independently selected from the group consisting of hydrogen and optionally substituted -C_1-C_4 alkyl, optionally substituted -C(O)-C_1-C_4 alkyl, and -C(O)H;

R^1 and R^2 are each independently selected from the group consisting of halogen, optionally substituted -C_1-C_4 alkyl, optionally substituted -S-C_1-C_3 alkyl, optionally substituted -C_2-C_4 alkenyl, optionally substituted -C_2-C_4 alkynyl, -CF_3, -OCF_3, optionally substituted-O-C_1-C_3 alkyl, and cyano;

R^3 and R^4 are each independently selected from the group consisting of hydrogen, halogen, -CF_3, -OCF_3, cyano, optionally substituted -C_1-C_{12} alkyl, optionally substituted -C_2-C_{12} alkenyl, optionally substituted -C_2-C_{12} alkynyl, optionally substituted -$(CR^a{}_2)_m$aryl, optionally substituted -$(CR^a{}_2)_m$cycloalkyl, optionally substituted -$(CR^a{}_2)_m$heterocycloalkyl, -OR^d, -SR^d, -S(=O)R^e, -S(=O)$_2R^e$, -S(=O)$_2NR^fR^g$, -C(O)NR^fR^g, -C(O)OR^h, -C(O)R^e, -N(R^b)C(O)R^e, -N(R^b)C(O)NR^fR^g, -N(R^b)S(=O)$_2R^e$, -N(R^b)S(=O)$_2NR^fR^g$, and -NR^fR^g;

Each R^d is selected from the group consisting of optionally substituted -C_1-C_{12} alkyl, optionally substituted -C_2-C_{12} alkenyl, optionally substituted -C_2-C_{12} alkynyl, optionally substituted -$(CR^b{}_2)_n$aryl, optionally substituted -$(CR^b{}_2)_n$cycloalkyl, optionally substituted -$(CR^b{}_2)_n$heterocycloalkyl, and -C(O)NR^fR^g;

Each R^e is selected from the group consisting of optionally substituted -C_1-C_{12} alkyl, optionally substituted -C_2-C_{12} alkenyl, optionally substituted -C_2-C_{12} alkynyl, optionally substituted -$(CR^a{}_2)_n$aryl, optionally substituted -$(CR^a{}_2)_n$cycloalkyl, and optionally substituted -$(CR^a{}_2)_n$heterocycloalkyl;

R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_{12} alkyl, optionally substituted -C_2-C_{12} alkenyl, optionally substituted -C_2-C_{12} alkynyl, optionally substituted -$(CR^b{}_2)_n$aryl, optionally substituted -$(CR^b{}_2)_n$cycloalkyl, and optionally substituted -$(CR^b{}_2)_n$heterocycloalkyl, or R^f

and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup selected from the group consisting of O, NR^c, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-4 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$;

Each R^h is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b_2)_n$aryl, optionally substituted $-(CR^b_2)_n$cycloalkyl, and optionally substituted $-(CR^b_2)_n$heterocycloalkyl;

R^5 is selected from the group consisting of -OH, optionally substituted $-OC_1-C_6$ alkyl, $-OC(O)R^e$, $-OC(O)OR^h$, -F, $-NHC(O)R^e$, $-NHS(=O)R^e$, $-NHS(=O)_2R^e$, $-NHC(=S)NH(R^h)$, and $-NHC(O)NH(R^h)$;

R^7 is selected from the group consisting of hydrogen, halogen, amino, hydroxyl, $-O-C_1-C_4$ alkyl, -SH and $-S-C_1-C_4$ alkyl;

X is $P(O)YR^{11}Y'R^{11}$;

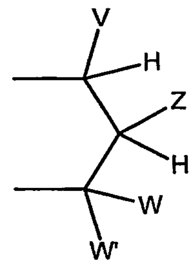
Y and Y' are each independently selected from the group consisting of -O-, and $-NR^v-$; when Y and Y' are -O- , R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, $-C(R^z)_2OC(O)NR^z_2$, $-NR^z-C(O)-R^y$, $-C(R^z)_2-OC(O)R^y$, $-C(R^z)_2-O-C(O)OR^y$, $-C(R^z)_2OC(O)SR^y$, -alkyl-S-$C(O)R^y$, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy;

when Y and Y' are $-NR^v-$, then R^{11} attached to $-NR^v-$ is independently selected from the group consisting of -H, $-[C(R^z)_2]_q-COOR^y$, $-C(R^x)_2COOR^y$, $-[C(R^z)_2]_q-C(O)SR^y$, and -cycloalkylene-$COOR^y$;

when Y is -O- and Y' is NR^v, then R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, $-C(R^z)_2OC(O)NR^z_2$, $-NR^z-C(O)-R^y$, $-C(R^z)_2-OC(O)R^y$, $-C(R^z)_2-O-C(O)OR^y$, $-C(R^z)_2OC(O)SR^y$, -alkyl-S-$C(O)R^y$, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy; and R^{11} attached to $-NR^v-$ is independently selected from

the group consisting of -H, $-[C(R^z)_2]_q-COOR^y$, $-C(R^x)_2COOR^y$, $-[C(R^z)_2]_q-C(O)SR^y$, and -cycloalkylene-$COOR^y$;

or when Y and Y' are independently selected from -O- and $-NR^v-$, then together R^{11} and R^{11} are -alkyl-S-S-alkyl- to form a cyclic group, or together R^{11} and R^{11} are the group:



wherein:

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy, alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, that is fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0–2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of $-CHR^zOH$, $-CHR^zOC(O)R^y$, $-CHR^zOC(S)R^y$, $-CHR^zOC(S)OR^y$, $-CHR^zOC(O)SR^y$, $-CHR^zOCO_2R^y$, $-OR^z$, $-SR^z$, $-CHR^zN_3$, $-CH_2$aryl, -CH(aryl)OH, $-CH(CH{=}CR^z_2)OH$, $-CH(C{\equiv}CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2NH$aryl, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl;

Each R^x is independently selected from the group consisting of -H, and alkyl, or together R^x and R^x form a cyclic alkyl group;

Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl;

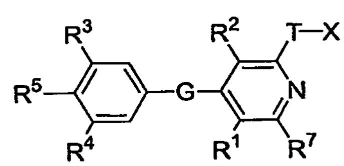
with the provisos that:

a) when G is -O-, T is $-NH-CH_2-$, R^1 and R^2 are each chloro, R^3 is *iso*-propyl, R^4 is hydrogen, R^7 is fluoro, and R^5 is –OH, then X is not $P(O)(OH)_2$, $P(O)(OH)(OCH_3)$ or $P(O)(OCH_3)_2$;

b) V, Z, W, W' are not all -H; and

c) when Z is $-R^z$, then at least one of V, W, and W' is not -H, alkyl, aralkyl, or heterocycloalkyl.

In an additional aspect, the invention relates to compounds of Formula III, stereoisomers, pharmaceutically acceptable salts and prodrugs thereof and pharmaceutically acceptable salts of the prodrugs as represented by Formula III:



wherein:

G is selected from the group consisting of -O-, -S-, -S(=O)-, $-S(=O)_2-$, $-CH_2-$, $-CF_2-$, -CHF-, -C(O)-, -CH(OH)-, -NH-, and $-N(C_1\text{-}C_4\text{ alkyl})-$;

T is selected from the group consisting of $-(CR^a_2)_k-$, $-CR^b=CR^b-(CR^a_2)_n-$, $-(CR^a_2)_n-CR^b=CR^b-$, $-(CR^a_2)-CR^b=CR^b-(CR^a_2)-$, $-O(CR^b_2)(CR^a_2)_n-$, $-S(CR^b_2)(CR^a_2)_n-$, $-N(R^c)(CR^b_2)(CR^a_2)_n-$, $-N(R^b)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nCH(NR^bR^c)-$, $-C(O)(CR^a_2)_m-$, $-(CR^a_2)_mC(O)-$, $-(CR^a_2)C(O)(CR^a_2)_n-$, $-(CR^a_2)_nC(O)(CR^a_2)-$, and $-C(O)NH(CR^b_2)(CR^a_2)_p-$;

k is an integer from 0-4;

m is an integer from 0-3;

n is an integer from 0-2;

p is an integer from 0-1;

Each R^a is independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_4$ alkyl, halogen, -OH, optionally substituted $-O-C_1-C_4$ alkyl, $-OCF_3$, optionally substituted $-S-C_1-C_4$ alkyl, $-NR^bR^c$, optionally substituted $-C_2-C_4$ alkenyl, and optionally substituted $-C_2-C_4$ alkynyl; with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom;

Each R^b is independently selected from the group consisting of hydrogen and optionally substituted $-C_1-C_4$ alkyl;

Each R^c is independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_4$ alkyl, optionally substituted $-C(O)-C_1-C_4$ alkyl, and -C(O)H;

R^1 and R^2 are each independently selected from the group consisting of halogen, optionally substituted $-C_1-C_4$ alkyl, optionally substituted $-S-C_1-C_3$ alkyl, optionally substituted $-C_2-C_4$ alkenyl, optionally substituted $-C_2-C_4$ alkynyl, $-CF_3$, $-OCF_3$, optionally substituted-$O-C_1-C_3$ alkyl, and cyano;

R^3 and R^4 are each independently selected from the group consisting of hydrogen, halogen, $-CF_3$, $-OCF_3$, cyano, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a_2)_m$aryl, optionally substituted $-(CR^a_2)_m$cycloalkyl, optionally substituted $(CR^a_2)_m$heterocycloalkyl, $-OR^d$, $-SR^d$, $-S(=O)R^e$, $-S(=O)_2R^e$, $-S(=O)_2NR^fR^g$, $-C(O)NR^fR^g$, $-C(O)OR^h$, $-C(O)R^e$, $-N(R^b)C(O)R^e$, $-N(R^b)C(O)NR^fR^g$, $-N(R^b)S(=O)_2R^e$, $-N(R^b)S(=O)_2NR^fR^g$, and $-NR^fR^g$;

Each R^d is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl,

optionally substituted -$(CR^b{}_2)_n$aryl, optionally substituted -$(CR^b{}_2)_n$cycloalkyl, optionally substituted -$(CR^b{}_2)_n$heterocycloalkyl, and -C(O)NR^fR^g;

Each R^e is optionally substituted -C_1-C_{12} alkyl, optionally substituted -C_2-C_{12} alkenyl, optionally substituted -C_2-C_{12} alkynyl, optionally substituted -$(CR^a{}_2)_n$aryl, optionally substituted -$(CR^a{}_2)_n$cycloalkyl, and optionally substituted -$(CR^a{}_2)_n$heterocycloalkyl;

R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted -C_1-C_{12} alkyl, optionally substituted -C_2-C_{12} alkenyl, optionally substituted -C_2-C_{12} alkynyl, optionally substituted -$(CR^b{}_2)_n$aryl, optionally substituted -$(CR^b{}_2)_n$cycloalkyl, and optionally substituted -$(CR^b{}_2)_n$heterocycloalkyl, or R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup selected from the group of O, NR^c, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-4 substituents selected from the group consisting of optionally substituted -C_1-C_4 alkyl, -OR^b, oxo, cyano, -CF_3, optionally substituted phenyl, and -C(O)OR^h;

Each R^h is selected from the group consisting of optionally substituted -C_1-C_{12} alkyl, optionally substituted -C_2-C_{12} alkenyl, optionally substituted -C_2-C_{12} alkynyl, optionally substituted -$(CR^b{}_2)_n$aryl, optionally substituted -$(CR^b{}_2)_n$cycloalkyl, and optionally substituted -$(CR^b{}_2)_n$heterocycloalkyl;

R^5 is selected from the group consisting of -OH, optionally substituted -OC_1-C_6 alkyl, -OC(O)R^e, -OC(O)OR^h, -F, -NHC(O)R^e, -NHS(=O)R^e, -NHS$(=O)_2R^e$, -NHC(=S)NH(R^h), and -NHC(O)NH(R^h);

R^7 is selected from the group consisting of hydrogen, halogen, amino, hydroxyl, -O-C_1-C_4 alkyl, -SH and -S-C_1-C_4 alkyl;

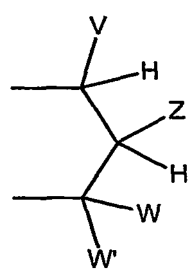
X is P(O)$YR^{11}Y'R^{11}$;

Y and Y' are each independently selected from the group consisting of -O-, and -NR^v-; when Y and Y' are -O- , R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, -$C(R^z)_2OC(O)NR^z{}_2$, -NR^z-C(O)-R^y, -$C(R^z)_2$- OC(O)R^y, -$C(R^z)_2$-O-C(O)OR^y, -$C(R^z)_2OC(O)SR^y$, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy;

when Y and Y' are -NR^v-, then R^{11} attached to -NR^v- is independently selected from the group consisting of -H, -[C(R^z)$_2$]$_q$-COOR^y, -C(R^x)$_2$COOR^y, -[C(R^z)$_2$]$_q$-C(O)SR^y, and -cycloalkylene-COOR^y;

when Y is -O- and Y' is NR^v, then R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH$_2$-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, -C(R^z)$_2$OC(O)NR^z$_2$, -NR^z-C(O)-R^y, -C(R^z)$_2$- OC(O)R^y, -C(R^z)$_2$-O-C(O)OR^y, -C(R^z)$_2$OC(O)SR^y, -alkyl-S-C(O)R^y, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy; and R^{11} attached to -NR^v- is independently selected from the group consisting of -H, -[C(R^z)$_2$]$_q$-COOR^y, -C (R^x)$_2$COOR^y, -[C(R^z)$_2$]$_q$-C(O)SR^y, and -cycloalkylene-COOR^y;

or when Y and Y' are independently selected from -O- and -NR^v-, then together R^{11} and R^{11} are -alkyl-S-S-alkyl- to form a cyclic group, or together R^{11} and R^{11} are the group:



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wherein:

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0 – 1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy, alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, that is fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0–2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of $-CHR^zOH$, $-CHR^zOC(O)R^y$, $-CHR^zOC(S)R^y$, $-CHR^zOC(S)OR^y$, $-CHR^zOC(O)SR^y$, $-CHR^zOCO_2R^y$, $-OR^z$, $-SR^z$, $-CHR^zN_3$, $-CH_2$aryl, -CH(aryl)OH, $-CH(CH{=}CR^z_2)OH$, $-CH(C{\equiv}CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2NH$aryl, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl;

Each R^x is independently selected from the group consisting of -H, and alkyl, or together R^x and R^x form a cyclic alkyl group;

Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl;

with the provisos that:

a) when G is selected from the group consisting of -O-, -S-, -S(=O)-, -S(=O)$_2$-, $-CH_2-$, -C(O)- and $-NR^b-$; T is -A-B- where A is selected from the group consisting of

$-NR^b-$, -O-, $-CH_2-$ and -S- and B is selected from the group consisting of a bond and substituted or unsubstituted C_1-C_3 alkyl; R^3 is selected from the group consisting of

halogen, trifluoromethyl, substituted or unsubstituted C_1-C_6 alkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl, aryloxy, substituted amide, sulfone, sulfonamide and C_3-C_7 cycloalkyl, wherein said aryl, heteroaryl or cycloalkyl ring(s) are attached or fused to the aromatic; R^4 is selected from the group consisting of hydrogen, halogen, substituted or unsubstituted C_1-C_6 alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; R^1 and R^2 are each independently selected from the group consisting of halogen, substituted or unsubstituted C_1-C_4 alkyl, and substituted or unsubstituted C_3-C_5 cycloalkyl; R^7 is selected selected from the group consisting of hydrogen, halogen, amino, hydroxyl, -O-C_1-C_4 alkyl, -SH and -S-C_1-C_4 alkyl; and R^5 is selected from the group consisting of hydroxyl, optionally substituted -OC_1-C_6 alkyl, and -OC(O)R^e; then X is not -P(O)(OH)$_2$;

b) V, Z, W, W' are not all -H; and

c) when Z is -R^z, then at least one of V, W, and W' is not -H, alkyl, aralkyl, or heterocycloalkyl.

In another aspect, when G is -O-, T is -NH-CH$_2$-, R^1 and R^2 are each chloro, R^3 is *iso*-propyl, R^7 is fluoro and R^5 is –OH, then R^4 is not hydrogen. In a further aspect, when G is selected from the group consisting of oxygen, sulfur, sulfoxide, sulfonyl, -CH$_2$-, -C(O)- and –NR^b-; T is –A-B- where A is selected from the group consisting of –NR^b-, -O-, -CH$_2$- and –S- and B is selected from the group consisting of a bond and substituted or unsubstituted C_1-C_3 alkyl; R^3 is selected from the group consisting of halogen, trifluoromethyl, substituted or unsubstituted C_1-C_6 alkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl, aryloxy, substituted amide, sulfone, sulfonamide and C_3-C_7 cycloalkyl, wherein said aryl, heteroaryl or cycloalkyl ring(s) are attached or fused to the aromatic; R^4 is selected from the group consisting of hydrogen, halogen, substituted or unsubstituted C_1-C_6 alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; R^1 and R^2 are each independently selected from the group consisting of halogen, substituted or unsubstituted C_1-C_4 alkyl, and substituted or unsubstituted C_3-C_5 cycloalkyl; and R^7 is selected selected from the group consisting of hydrogen, halogen, amino, hydroxyl,
-O-C_1-C_4 alkyl, -SH and -S-C_1-C_4 alkyl; then R^5 is not hydroxyl, optionally substituted -OC_1-C_6 alkyl, or -OC(O)R^e.

In one aspect, G is selected from the group consisting of -O- and -CH$_2$-. In a further aspect, G is -O-. In another aspect, G is -S-. In a further aspect, G is -S(=O)-. In another aspect, G is -S(=O)$_2$-. In a further aspect, G is -CH$_2$-. In another aspect, G

is $-CF_2-$. In a further aspect, G is -CHF-. In another aspect, G is -C(O)-. In another aspect, G is -CH(OH)-. In a further aspect,G is -NH-. In another aspect, G is $-N(C_1-C_4$ alkyl)-.

In another aspect, T is selected from the group consisting of $-(CR^a_2)_n-$, $-O(CR^b_2)(CR^a_2)_p-$, $-N(R^c)(CR^b_2)(CR^a_2)_p-$, $-S(CR^b_2)(CR^a_2)_p-$, $-NR^b(CO)-$, and $-CH_2CH(NR^cR^b)-$. In a further aspect, T is $-(CR^a_2)_k-$. In another aspect, T is $-CR^b{=}CR^b-(CR^a_2)_n-$. In a further aspect, T is $-(CR^a_2)_n-CR^b{=}CR^b-$. In another aspect, T is $-(CR^a_2)-CR^b{=}CR^b-(CR^a_2)-$. In a further aspect, T is $-O(CR^b_2)(CR^a_2)_n-$. In another aspect, T is $-S(CR^b_2)(CR^a_2)_n-$. In a further aspect, T is $-N(R^c)(CR^b_2)(CR^a_2)_n-$. In another aspect, T is $-N(R^b)C(O)(CR^a_2)_n-$. In a further aspect, T is $-(CR^a_2)_nCH(NR^bR^c)-$. In another aspect, T is $-C(O)(CR^a_2)_m-$. In a further aspect, T is $-(CR^a_2)_mC(O)-$. In another aspect, T is $-(CR^a_2)C(O)(CR^a_2)_n-$. In a further aspect, T is $-(CR^a_2)_nC(O)(CR^a_2)-$. In yet another aspect, T is $-C(O)NH(CR^b_2)(CR^a_2)_p-$.

In one aspect k is 0. In a further aspect, k is 1. In an additional aspect, k is 2. In a further aspect, k is 3. In yet another aspect, k is 4. In one aspect m is 0. In a further aspect, m is 1. In an additional aspect, m is 2. In a further aspect, m is 3. In one aspect n is 0. In a further aspect, n is 1. In an additional aspect, n is 2. In one aspect, p is 0. In another aspect, p is 1.

In one aspect, each R^a is hydrogen with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is optionally substituted $-C_1-C_4$ alkyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is halogen with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is –OH with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is optionally substituted $-O-C_1-C_4$ alkyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is $-OCF_3$ with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is optionally substituted $-S-C_1-C_4$ alkyl with the proviso that when one R^a is attached to C

through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is $-NR^bR^c$ with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is optionally substituted $-C_2-C_4$ alkenyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is optionally substituted $-C_2-C_4$ alkynyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom.

In one aspect, R^b is hydrogen. In an additional aspect, R^b is optionally substituted $-C_1-C_4$ alkyl.

In one aspect, R^c is hydrogen. In another aspect, R^c is optionally substituted $-C_1-C_4$ alkyl. In a further aspect, R^c is optionally substituted $-C(O)-C_1-C_4$ alkyl. In yet another aspect, R^c is $-C(O)H$.

In a further aspect, R^1 and R^2 are the same and are selected from the group consisting of halogen, $-C_1-C_4$ alkyl, $-CF_3$, and cyano. In yet another aspect, R^1 and R^2 are different and are selected from the group consisting of halogen, $-C_1-C_4$ alkyl, $-CF_3$, and cyano. In an additional aspect, R^1 and R^2 are each halogen. In another aspect, R^1 and R^2 are each optionally substituted $-C_1-C_4$ alkyl. In a further aspect, R^1 and R^2 are each optionally substituted $-S-C_1-C_3$ alkyl. In another aspect, R^1 and R^2 are each optionally substituted $-C_2-C_4$ alkenyl. In a further aspect, R^1 and R^2 are each optionally substituted $-C_2-C_4$ alkynyl. In another aspect, R^1 and R^2 are each $-CF_3$. In a further aspect, R^1 and R^2 are each $-OCF_3$. In another aspect, R^1 and R^2 are each optionally substituted-$O-C_1-C_3$ alkyl. In a further aspect, R^1 and R^2 are each cyano.

In yet another aspect, R^3 and R^4 are each hydrogen. In another aspect, R^3 and R^4 are each halogen. In a further aspect, R^3 and R^4 are each $-CF_3$. In another aspect, R^3 and R^4 are each $-OCF_3$. In a further aspect, R^3 and R^4 are each cyano. In another aspect, R^3 and R^4 are each optionally substituted $-C_1-C_{12}$ alkyl. In a further aspect, R^3 and R^4 are each optionally substituted $-C_2-C_{12}$ alkenyl. In another aspect, R^3 and R^4 are each optionally substituted $-C_2-C_{12}$ alkynyl. In a further aspect, R^3 and R^4 are each optionally substituted $-(CR^a{}_2)_m$aryl. In another aspect, R^3 and R^4 are each optionally substituted $-(CR^a{}_2)_m$cycloalkyl. In a further aspect, R^3 and R^4 are each optionally substituted $-(CR^a{}_2)_m$heterocycloalkyl. In another aspect, R^3 and R^4 are each $-OR^d$. In another aspect, R^3 and R^4 are each $-SR^d$. In a further aspect, R^3 and R^4 are

each $-S(=O)R^e$. In another aspect, R^3 and R^4 are each $-S(=O)_2R^e$. In a further aspect, R^3 and R^4 are each $-S(=O)_2NR^fR^g$. In another aspect, R^3 and R^4 are each $-C(O)NR^fR^g$. In a further aspect, R^3 and R^4 are each $-C(O)OR^h$. In another aspect, R^3 and R^4 are each $-C(O)R^e$. In afurther aspect, R^3 and R^4 are each $-N(R^b)C(O)R^e$. In another aspect, R^3 and R^4 are each $-N(R^b)C(O)NR^fR^g$. In a further aspect, R^3 and R^4 are each $-N(R^b)S(=O)_2R^e$. In another aspect, R^3 and R^4 are each $-N(R^b)S(=O)_2NR^fR^g$. In a further aspect, R^3 and R^4 are each $-NR^fR^g$.

In another aspect, R^4 is selected from the group consisting of hydrogen, halogen, $-C_1-C_4$ alkyl, cyano and CF_3. In a further aspect, R^3 is selected from the group consisting of halogen, optionally substituted $-C_1-C_6$ alkyl, $-CF_3$, cyano, $-C(O)NR^fR^g$, optionally substituted $-(CR^a_2)_n$aryl, $-SO_2NR^fR^g$, and $-SO_2R^e$.

In another aspect, each R^d is optionally substituted $-C_1-C_{12}$ alkyl. In a further aspect, each R^d is optionally substituted $-C_2-C_{12}$ alkenyl. In another aspect, each R^d is optionally substituted $-C_2-C_{12}$ alkynyl. In a further aspect, each R^d is optionally substituted $-(CR^b_2)_n$aryl. In another aspect, each R^d is optionally substituted $-(CR^b_2)_n$cycloalkyl. In a further aspect, each R^d is optionally substituted $-(CR^b_2)_n$heterocycloalkyl. In another aspect, each R^d is $-C(O)NR^fR^g$.

In an additional aspect, R^e is optionally substituted $-C_1-C_{12}$ alkyl. In another aspect, R^e is optionally substituted $-C_2-C_{12}$ alkenyl. In a further aspect, R^e is optionally substituted $-C_2-C_{12}$ alkynyl. In another aspect, R^e is optionally substituted $-(CR^a_2)_n$aryl. In a further aspect, R^e is optionally substituted $-(CR^a_2)_n$cycloalkyl. In another aspect, R^e is optionally substituted $-(CR^a_2)_n$heterocycloalkyl.

In one aspect, R^f and R^g are each hydrogen. In an additional aspect, R^f and R^g are each optionally substituted $-C_1-C_{12}$ alkyl. In another aspect, R^f and R^g are each optionally substituted $-C_2-C_{12}$ alkenyl. In an additional aspect, R^f and R^g are each optionally substituted $-C_2-C_{12}$ alkynyl. In a further aspect, R^f and R^g are each optionally substituted $-(CR^b_2)_n$aryl. In an additional aspect, R^f and R^g are each optionally substituted $-(CR^b_2)_n$cycloalkyl. In another aspect, R^f and R^g are each optionally substituted $-(CR^b_2)_n$heterocycloalkyl.

In an additional aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup which is O. In another aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup which is NR^c. In another aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second

heterogroup which is S. In one aspect, R^f and R^g may together form an unsubstituted heterocyclic ring, which may contain a second heterogroup. In another aspect, the optionally substituted heterocyclic ring may be substituted with 1 substituent selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$. In further aspect, the optionally substituted heterocyclic ring may be substituted with 2 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$. In another aspect, the optionally substituted heterocyclic ring may be substituted with 3 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$. In a further aspect, the optionally substituted heterocyclic ring may be substituted with 4 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$.

In a further aspect, R^h is optionally substituted $-C_1-C_{12}$ alkyl. In another aspect, R^h is optionally substituted $-C_2-C_{12}$ alkenyl. In a further aspect, R^h is optionally substituted $-C_2-C_{12}$ alkynyl. In another aspect, R^h is optionally substituted $-(CR^b{}_2)_n$aryl. In a further aspect, R^h is optionally substituted $-(CR^b{}_2)_n$cycloalkyl. In another aspect, R^h is optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl.

In one aspect, R^5 is selected from the group consisting of -OH, $-OC(O)R^e$, $-OC(O)OR^h$, -F, and $-NHC(O)R^e$. In an additional aspect, R^5 is optionally substituted $-OC_1-C_6$ alkyl. In another aspect, R^5 is $-OC(O)R^e$. In a further aspect, R^5 is -$OC(O)OR^h$. In another aspect, R^5 is –F. In another aspect, R^5 is $-NHC(O)R^e$. In a further aspect, R^5 is $-NHS(=O)R^e$. In another aspect, R^5 is $-NHS(=O)_2R^e$. In a further aspect, R^5 is
$-NHC(=S)NH(R^h)$. In another aspect, R^5 is $-NHC(O)NH(R^h)$.

In one aspect, X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCR^z{}_2OC(O)R^y]_2$, $-P(O)[-OCR^z{}_2OC(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y]_2$, $-P(O)[-N(H)CR^z{}_2C(O)OR^y][-OR^{11}]$, and $-P(O)[-OCH(V)CH_2CH_2O-]$, wherein V is selected from the group consisting of optionally substituted aryl, aryl, heteroaryl, and optionally substituted heteroaryl.

In another aspect, R^7 is selected from the group consisting of hydrogen, fluoro, chloro, amino, hydroxyl, and $-O-CH_3$.

In one aspect, G is selected from the group consisting of -O- and -CH_2-; T is selected from the group consisting of -$(CR^a{}_2)_n$-, -O$(CR^b{}_2)(CR^a{}_2)_p$-, -N$(R^c)(CR^b{}_2)(CR^{a2})_p$-, -S$(CR^b{}_2)(CR^a{}_2)_p$-, -$NR^b$(CO)-, and -$CH_2CH(NR^cR^b)$-; R^1 and R^2 are each independently selected from the group consisting of halogen, -C_1-C_4 alkyl, -CF_3, and cyano; R^4 is selected from the group consisting of hydrogen, halogen, -C_1-C_4 alkyl, cyano and CF_3; R^5 is selected from the group consisting of -OH, -OC(O)R^e, -OC(O)OR^h, -F, and -NHC(O)R^e; R^3 is selected from the group consisting of halogen, optionally substituted -C_1-C_6 alkyl, -CF_3, cyano, -C(O)NR^fR^g, optionally substituted -$(CR^a{}_2)_n$aryl, -$SO_2NR^fR^g$, and -SO_2R^e; R^7 is selected from the group consisting of hydrogen, fluoro, chloro, amino, hydroxyl, and -O-CH_3; and X is selected from the group consisting of -PO_3H_2, -P(O)[-$OCR^z{}_2OC(O)R^y$]$_2$, -P(O)[-$OCR^z{}_2OC(O)OR^y$]$_2$, -P(O)[-N(H)$CR^z{}_2C(O)OR^y$]$_2$, -P(O)[-N(H)$CR^z{}_2C(O)OR^y$][-OR^{11}] and -P(O)[-OCH(V)CH_2CH_2O-], wherein V is selected from the group consisting of optionally substituted aryl, aryl, heteroaryl, and optionally substituted heteroaryl.

In a further aspect, when G is -O-, T is -CH_2-, R^1 and R^2 are chloro, R^3 is *iso*-propyl, R^7 is fluoro, and R^5 is -OH, then R^4 is not hydrogen. In another aspect, when G is selected from the group consisting of –O- and -CH_2-; T is –A-B- where A is selected from the group consisting of –NR^b-, -O-, -CH_2- and –S- and B is selected from the group consisting of a bond and substituted or unsubstituted C_1-C_3 alkyl; R^3 is selected from the group consisting of halogen, trifluoromethyl, substituted or unsubstituted C_1-C_6 alkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl, aryloxy, substituted amide, sulfone, sulfonamide and C_3-C_7 cycloalkyl, wherein said aryl, heteroaryl or cycloalkyl ring(s) are attached or fused to the aromatic; R^4 is selected from the group consisting of hydrogen, halogen, and substituted or unsubstituted C_1-C_4 alkyl; R^1 and R^2 are each independently selected from the group consisting of halogen and substituted or unsubstituted -C_1-C_4 alkyl; and R^7 is selected from the group consisting of hydrogen, fluoro, chloro, amino, hydroxyl, and -O-CH_3; then R^5 is not hydroxyl, optionally substituted -OC_1-C_6 alkyl, or -OC(O)R^e.

In an additional aspect, T is -N(H)C(O)-; R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano; R^4 is selected from the group consisting of hydrogen and iodo; R^5 is selected from the group consisting of –OH and -OC(O)R^e; R^3 is selected from the group consisting of iodo,

bromo, optionally substituted -C_1-C_6 alkyl, optionally substituted -CH_2aryl, optionally substituted -CH(OH)aryl, -C(O)-amido, -S(=O)$_2$-amido, wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methypiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and -SO_2R^e wherein R^e is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl; and R^7 is selected from the group consisting of hydrogen and fluoro.

In an additional aspect, T is -N(H)C(O)-; G is -O-; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is –OH; R^3 is -*iso*-propyl; and R^7 is fluoro.

In an additional aspect, T is -N(H)C(O)-; G is -O-; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is –OH; R^3 is -*iso*-propyl; R^7 is fluoro; X is selected from the group consisting of -PO_3H_2, -P(O)[-OCH_2OC(O)-*t*-butyl]$_2$, -P(O)[-OCH_2OC(O)O-*i*-propyl]$_2$, -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$_2$, -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3]$_2$, -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3][3,4-methylenedioxyphenyl], -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3][3,4-methylenedioxyphenyl], and -P(O)[-OCH(3-chlorophenyl)CH_2CH_2O-].

In another aspect, T is -OCH_2-; R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano; R^4 is selected from the group consisting of hydrogen and iodo; R^5 is selected from the group consisting of -OH, and -OC(O)R^e; R^3 is selected from the group consisting of iodo, bromo, optionally substituted C_1-C_6 alkyl, optionally substituted -CH_2aryl, optionally substituted -CH(OH)aryl, -C(O)-amido, -S(=O)$_2$-amido, wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methylpiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and -SO_2R^e wherein R^e is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl; and R^7 is selected from the group consisting of hydrogen and fluoro.

In another aspect, T is -OCH_2-; G is -O-; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and R^7 is fluoro.

In another aspect, T is -OCH_2-; G is -O-; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; R^7 is fluoro; and X is selected from the group consisting of -PO_3H_2, -P(O)[-OCH_2OC(O)-*t*-butyl]$_2$, -P(O)[-OCH_2OC(O)O-*i*-propyl]$_2$, -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$_2$, -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3]$_2$, -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3][3,4-methylenedioxyphenyl], -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3][3,4-methylenedioxyphenyl], and -P(O)[-OCH(3-chlorophenyl)CH_2CH_2O-].

In an additional aspect, T is $-CH_2-$; R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano; R^4 is selected from the group consisting of hydrogen and iodo; R^5 is selected from the group consisting of -OH, and $-OC(O)R^e$; R^3 is selected from the group consisting of iodo, bromo, optionally substituted C_1-C_6 alkyl, optionally substituted $-CH_2$aryl, optionally substituted -CH(OH)aryl, -C(O)-amido, $-S(=O)_2$-amido wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methylpiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and $-SO_2R^e$ wherein R^e is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl; and R^7 is selected from the group consisting of hydrogen and fluoro.

In an additional aspect, T is $-CH_2-$; G is -O-; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is -OH; R^3 is *i*-propyl; and R^7 is fluoro.

In an additional aspect, T is $-CH_2-$; G is -O-; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is -OH; R^3 is *i*-propyl; R^7 is fluoro; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCH_2OC(O)$-*t*-butyl$]_2$, $-P(O)[-OCH_2OC(O)O$-*i*-propyl$]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$, $-P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], $-P(O)[-N(H)C(CH_3)_2C(O)OCH_2CH_3]$[3,4-methylenedioxyphenyl], and $-P(O)[-OCH(3\text{-chlorophenyl})CH_2CH_2O-]$.

In a further aspect, T is $-CH_2CH_2-$; R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano; R^4 is selected from the group consisting of hydrogen and iodo; R^5 is selected from the group consisting of -OH and $-OC(O)R^e$; R^3 is selected from the group consisting of iodo, bromo, optionally substituted C_1-C_6 alkyl, optionally substituted $-CH_2$aryl, optionally substituted -CH(OH)aryl, -C(O)-amido, $-S(=O)_2$-amido, wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methylpiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and $-SO_2R^e$ wherein R^e is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl; and R^7 is selected from the group consisting of hydrogen and fluoro.

In another aspect, T is $-CH_2CH_2-$; G is -O-; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; and R^7 is fluoro.

In another aspect, T is $-CH_2CH_2-$; G is -O-; R^1 and R^2 are each chloro; R^4 is hydrogen; R^5 is -OH; R^3 is *iso*-propyl; R^7 is fluoro; and X is selected from the group consisting of $-PO_3H_2$, $-P(O)[-OCH_2OC(O)$-*t*-butyl$]_2$, $-P(O)[-OCH_2OC(O)O$-*i*-propyl$]_2$,

-P (O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$_2$, -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3]$_2$, -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3][3,4-methylenedioxyphenyl], -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3][3,4-methylenedioxyphenyl], and -P(O)[-OCH(3-chlorophenyl)CH_2CH_2O-].

In another aspect, T is -$NHCH_2$-; R^1 and R^2 are each independently selected from the group consisting of iodo, bromo, chloro, methyl, and cyano; R^4 is selected from the group consisting of hydrogen and iodo; R^5 is selected from the group consisting of -OH, and -OC(O)R^e; R^3 is selected from the group consisting of iodo, bromo, optionally substituted C_1-C_6 alkyl, optionally substituted -CH_2aryl, optionally substituted -CH(OH)aryl, -C(O)-amido, -S(=O)$_2$-amido, wherein the amido group is selected from the group consisting of phenethylamino, piperidinyl, 4-methylpiperizinyl, morpholinyl, cyclohexylamino, anilinyl, and indolinyl, and -SO_2R^e wherein R^e is selected from the group consisting of phenyl, 4-chlorophenyl, 4-fluorophenyl, and 4-pyridyl; and R^7 is selected from the group consisting of hydrogen and fluoro.

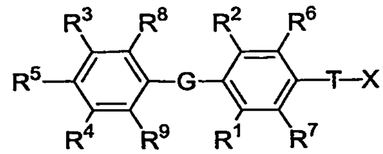
In yet another aspect, T is -$NHCH_2$-; G is –O-; R^1 and R^2 are each chloro; R^4 is selected from the group consisting of hydrogen and iodo R^5 is -OH; R^3 is *iso*-propyl; and R^7 is fluoro.

In another aspect, T is -$NHCH_2$-; G is –O-; R^1 and R^2 are each bromo; R^4 is selected from the group consisting of hydrogen and iodo R^5 is -OH; R^3 is *iso*-propyl; and R^7 is fluoro.

In another aspect, T is -$NHCH_2$-; G is –O-; R^1 and R^2 are each bromo; R^4 is selected from the group consisting of hydrogen and iodo R^5 is -OH; R^3 is *iso*-propyl; R^7 is fluoro; and X is selected from the group consisting of -PO_3H_2, -P(O)[-OCH_2OC(O)-*t*-butyl]$_2$, -P(O)[-OCH_2OC(O)O-*i*-propyl]$_2$, -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3]$_2$, -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3]$_2$, -P(O)[-N(H)CH(CH_3)C(O)OCH_2CH_3][3,4-methylenedioxyphenyl], -P(O)[-N(H)C(CH_3)$_2$C(O)OCH_2CH_3][3,4-methylenedioxyphenyl], and -P(O)[-OCH(3-chlorophenyl) CH_2CH_2O-].

In a further aspect, X is -PO_3H_2.

In a further aspect of the invention, the invention relates to compounds of Formula VIII:



Formula VIII

wherein:

G is selected from the group consisting of -O-, -S-, -S(=O)-, -S(=O)$_2$-, -Se-, -CH$_2$-, -CF$_2$-, -CHF-, -C(O)-, -CH(OH)-, -CH(C$_1$-C$_4$ alkyl)-, -CH(C$_1$-C$_4$ alkoxy)-, -C(=CH$_2$)-,-NH-, and -N(C$_1$-C$_4$ alkyl)-;

T is selected from the group consisting of -(CR$^a_2$)$_k$-, -CR^b=CR^b-(CR$^a_2$)$_n$-, -(CR$^a_2$)$_n$-CR^b=CR^b-, -(CR$^a_2$)-CR^b=CR^b-(CR$^a_2$)-, -O(CR$^b_2$)(CR$^a_2$)$_n$-, -S(CR$^b_2$)(CR$^a_2$)$_n$-, -N(R^c)(CR$^b_2$)(CR$^a_2$)$_n$-, -N(R^b)C(O)(CR$^a_2$)$_n$-, -(CR$^a_2$)$_n$CH(NR^{b}R^c)-, -C(O)(CR$^a_2$)$_m$-, -(CR$^a_2$)$_m$C(O)-, -(CR$^a_2$)C(O)(CR$^a_2$)$_n$-, -(CR$^a_2$)$_n$C(O)(CR$^a_2$)-, and -C(O)NH(CR$^b_2$)(CR$^a_2$)$_p$-;

k is an integer from 0-4;

m is an integer from 0-3;

n is an integer from 0-2;

p is an integer from 0-1;

Each R^a is independently selected from the group consisting of hydrogen, optionally substituted -C$_1$-C$_4$ alkyl, halogen, -OH, optionally substituted -O-C$_1$-C$_4$ alkyl, -OCF$_3$, optionally substituted -S-C$_1$-C$_4$ alkyl, -NR^{b}R^c, optionally substituted -C$_2$-C$_4$ alkenyl, and optionally substituted -C$_2$-C$_4$ alkynyl; with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom;

Each R^b is independently selected from the group consisting of hydrogen and optionally substituted -C$_1$-C$_4$ alkyl;

Each R^c is independently selected from the group consisting of hydrogen and optionally substituted -C$_1$-C$_4$ alkyl, optionally substituted -C(O)-C$_1$-C$_4$ alkyl, and -C(O)H;

R^1, R^2, R^6, R^7, R^8, and R^9 are each independently selected from the group consisting of hydrogen, halogen, optionally substituted -C$_1$-C$_4$ alkyl, optionally substituted -S-C$_1$-C$_3$ alkyl, optionally substituted -C$_2$-C$_4$ alkenyl, optionally substituted -C$_2$-C$_4$ alkynyl, -CF$_3$, -OCF$_3$, optionally substituted-O-C$_1$-C$_3$ alkyl, and cyano; with the proviso that at least one of R^1 and R^2 is not hydrogen;

or R^6 and T are taken together along with the carbons they are attached to form a ring of 5 to 6 atoms 0 to 2 heteroatoms independently selected from $-NR^i-$, -O-, and –S-, with the proviso that when there are 2 heteroatoms in the ring and both heteroatoms are different than nitrogen then both heteroatoms have to be separated by at least one carbon atom; and X is attached to this ring by a direct bond to a ring carbon, or by $-(CR^a_2)-$ bonded to a ring carbon or a ring nitrogen;

R^i is selected from the group consisting of hydrogen, $-C(O)C_1-C_4$ alkyl, $-C_1-C_4$ alkyl, and $-C_1-C_4$-aryl;

R^3 and R^4 are each independently selected from the group consisting of hydrogen, halogen, $-CF_3$, $-OCF_3$, cyano, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a_2)_m$aryl, optionally substituted $-(CR^a_2)_m$cycloalkyl, optionally substituted $-(CR^a_2)_m$heterocycloalkyl, $-OR^d$, $-SR^d$, $-S(=O)R^e$, $-S(=O)_2R^e$, $-S(=O)_2NR^fR^g$, $-C(O)NR^fR^g$, $-C(O)OR^h$, $-C(O)R^e$, $-N(R^b)C(O)R^e$, $-N(R^b)C(O)NR^fR^g$, $-N(R^b)S(=O)_2R^e$, $-N(R^b)S(=O)_2NR^fR^g$, and $-NR^fR^g$;

Each R^d is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b_2)_n$aryl, optionally substituted $-(CR^b_2)_n$cycloalkyl, optionally substituted $-(CR^b_2)_n$heterocycloalkyl, and $-C(O)NR^fR^g$;

Each R^e is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^a_2)_n$aryl, optionally substituted $-(CR^a_2)_n$cycloalkyl, and optionally substituted $-(CR^a_2)_n$heterocycloalkyl;

R^f and R^g are each independently selected from the group consisting of hydrogen, optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b_2)_n$aryl, optionally substituted $-(CR^b_2)_n$cycloalkyl, and optionally substituted $-(CR^b_2)_n$heterocycloalkyl, or R^f and R^g may together form an optionally substituted heterocyclic ring, said heterocyclic ring may contain a second heterogroup within the ring selected from the group consisting of O, NR^c, and S, wherein said optionally substituted heterocyclic ring may be substituted with 0-4 substituents selected from the group consisting of optionally substituted $-C_1-C_4$ alkyl, $-OR^b$, oxo, cyano, $-CF_3$, optionally substituted phenyl, and $-C(O)OR^h$;

Each R^h is selected from the group consisting of optionally substituted $-C_1-C_{12}$ alkyl, optionally substituted $-C_2-C_{12}$ alkenyl, optionally substituted $-C_2-C_{12}$ alkynyl, optionally substituted $-(CR^b{}_2)_n$aryl, optionally substituted $-(CR^b{}_2)_n$cycloalkyl, and optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl;

R^5 is selected from the group consisting of -OH, optionally substituted $-OC_1-C_6$ alkyl, $-OC(O)R^e$, $-OC(O)OR^h$, -F, $-NHC(O)R^e$, $-NHS(=O)R^e$, $-NHS(=O)_2R^e$, $-NHC(=S)NH(R^h)$, and $-NHC(O)NH(R^h)$;

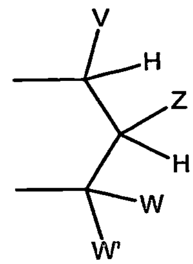
X is $P(O)YR^{11}Y'R^{11}$;

Y and Y' are each independently selected from the group consisting of -O-, and $-NR^v-$; when Y and Y' are -O- , R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, $-C(R^z)_2OC(O)NR^z{}_2$, $-NR^z-C(O)-R^y$, $-C(R^z)_2-OC(O)R^y$, $-C(R^z)_2-O-C(O)OR^y$, $-C(R^z)_2OC(O)SR^y$, -alkyl-S-$C(O)R^y$, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy;

when Y and Y' are $-NR^v-$, then R^{11} attached to $-NR^v-$ is independently selected from the group consisting of -H, $-[C(R^z)_2]_q-COOR^y$, $-C(R^x)_2COOR^y$, $-[C(R^z)_2]_q-C(O)SR^y$, and -cycloalkylene-$COOR^y$;

when Y is -O- and Y' is NR^v, then R^{11} attached to -O- is independently selected from the group consisting of -H, alkyl, optionally substituted aryl, optionally substituted heterocycloalkyl, optionally substituted CH_2-heterocycloakyl wherein the cyclic moiety contains a carbonate or thiocarbonate, optionally substituted -alkylaryl, $-C(R^z)_2OC(O)NR^z{}_2$, $-NR^z-C(O)-R^y$, $-C(R^z)_2-OC(O)R^y$, $-C(R^z)_2-O-C(O)OR^y$, $-C(R^z)_2OC(O)SR^y$, -alkyl-S-$C(O)R^y$, -alkyl-S-S-alkylhydroxy, and -alkyl-S-S-S-alkylhydroxy; and R^{11} attached to $-NR^v-$ is independently selected from the group consisting of -H, $-[C(R^z)_2]_q-COOR^y$, $-C(R^x)_2COOR^y$, $-[C(R^z)_2]_q-C(O)SR^y$, and -cycloalkylene-$COOR^y$;

or when Y and Y' are independently selected from -O- and $-NR^v-$, then together R^{11} and R^{11} are -alkyl-S-S-alkyl- to form a cyclic group, or together R^{11} and R^{11} are the group:



wherein:

V, W, and W' are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted aralkyl, heterocycloalkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, optionally substituted 1-alkenyl, and optionally substituted 1-alkynyl;

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, substituted with hydroxy, acyloxy, alkylthiocarbonyloxy, alkoxycarbonyloxy, or aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus; or

or together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, that is fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus;

or together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent selected from the group consisting of hydroxy, acyloxy, alkoxycarbonyloxy, alkylthiocarbonyloxy, and aryloxycarbonyloxy, attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus;

or together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

or together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0–2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl;

Z is selected from the group consisting of $-CHR^zOH$, $-CHR^zOC(O)R^y$, $-CHR^zOC(S)R^y$, $-CHR^zOC(S)OR^y$, $-CHR^zOC(O)SR^y$, $-CHR^zOCO_2R^y$, $-OR^z$,

$-SR^z$, $-CHR^zN_3$, $-CH_2$aryl, -CH(aryl)OH, $-CH(CH=CR^z_2)OH$, $-CH(C\equiv CR^z)OH$, $-R^z$, $-NR^z_2$, $-OCOR^y$, $-OCO_2R^y$, $-SCOR^y$, $-SCO_2R^y$, $-NHCOR^z$, $-NHCO_2R^y$, $-CH_2NH$aryl, $-(CH_2)_q-OR^z$, and $-(CH_2)_q-SR^z$;

q is an integer 2 or 3;

Each R^z is selected from the group consisting of R^y and -H;

Each R^y is selected from the group consisting of alkyl, aryl, heterocycloalkyl, and aralkyl;

Each R^x is independently selected from the group consisting of -H, and alkyl, or together R^x and R^x form a cyclic alkyl group;

Each R^v is selected from the group consisting of -H, lower alkyl, acyloxyalkyl, alkoxycarbonyloxyalkyl, and lower acyl.

with the provisos that:

a) V, Z, W, W' are not all -H; and

b) when Z is $-R^z$, then at least one of V, W, and W' is not -H, alkyl, aralkyl, or heterocycloalkyl.

In one aspect, when G is -O-, T is $-CH_2-$, R^1 and R^2 are each bromo, R^3 is *iso*-propyl, R^4 is hydrogen, and R^5 is –OH, then X is not $P(O)(OH)_2$ or $P(O)(OCH_2CH_3)_2$. In another aspect, when G is –O-, T is $-(CH_2)_{0-4}-$, R^1 and R^2 are independently halogen, alkyl of 1 to 3 carbons, and cycloalkyl of 3 to 5 carbons, R^3 is alkyl of 1 to 4 carbons or cycloalkyl of 3 to 7 carbons, R^4 is hydrogen, and R^5 is -OH, then X is not $-P(O)(OH)_2$ or $-P(O)(O\text{ lower alkyl})_2$. In a further aspect, when G is –O-, R^5 is $-NHC(O)R^e$, $-NHS(=O)_{1-2}R^e$, $-NHC(S)NH(R^h)$, or $-NHC(O)NH(R^h)$, T is $-(CH_2)_m-$, -CH=CH-, $-O(CH_2)_{1-2}-$, or $-NH(CH_2)_{1-2}-$, then X is not $-P(O)(OH)_2$ or $-P(O)(OH)NH_2$.

In one aspect, G is selected from the group consisting of -O- and $-CH_2-$. In a further aspect, G is -O-. In another aspect, G is -S-. In a further aspect, G is -S(=O)-. In another aspect, G is $-S(=O)_2-$. In a further aspect, G is $-CH_2-$. In another aspect, G is $-CF_2-$. In a further aspect, G is -CHF-. In another aspect, G is -C(O)-. In another aspect, G is -CH(OH)-. In a further aspect,G is -NH-. In another aspect, G is $-N(C_1-C_4$ alkyl)-. In yet another aspect, G is –Se-. In another aspect, G is $-CH(C_1-C_4$ alkyl)-. In another aspect, G is $-CH(C_1-C_4$ alkoxy)-. In another aspect, G is $-C(=CH_2)-$,

In another aspect, T is selected from the group consisting of $-(CR^a_2)_n-$, $-O(CR^b_2)(CR^a_2)_p-$, $-N(R^c)(CR^b_2)(CR^a_2)_p-$, $-S(CR^b_2)(CR^a_2)_p-$, $-NR^b(CO)-$, and $-CH_2CH(NR^cR^b)-$. In a further aspect, T is $-(CR^a_2)_k-$. In another aspect,

T is $-CR^b=CR^b-(CR^a_2)_n-$. In a further aspect, T is $-(CR^a_2)_n-CR^b=CR^b-$. In another aspect, T is $-(CR^a_2)-CR^b=CR^b-(CR^a_2)-$. In a further aspect, T is $-O(CR^b_2)(CR^a_2)_n-$. In another aspect, T is $-S(CR^b_2)(CR^a_2)_n-$. In a further aspect, T is $-N(R^c)(CR^b_2)(CR^a_2)_n-$. In another aspect, T is $-N(R^b)C(O)(CR^a_2)_n-$. In a further aspect, T is $-(CR^a_2)_nCH(NR^bR^c)-$. In another aspect, T is $-C(O)(CR^a_2)_m-$. In a further aspect, T is $-(CR^a_2)_mC(O)-$. In another aspect, T is $-(CR^a_2)C(O)(CR^a_2)_n-$. In a further aspect, T is $-(CR^a_2)_nC(O)(CR^a_2)-$. In yet another aspect, T is $-C(O)NH(CR^b_2)(CR^a_2)_p-$.

In one aspect k is 0. In a further aspect, k is 1. In an additional aspect, k is 2. In a further aspect, k is 3. In yet another aspect, k is 4. In one aspect m is 0. In a further aspect, m is 1. In an additional aspect, m is 2. In a further aspect, m is 3. In one aspect n is 0. In a further aspect, n is 1. In an additional aspect, n is 2. In one aspect, p is 0. In another aspect, p is 1.

In one aspect, each R^a is hydrogen with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is optionally substituted $-C_1-C_4$ alkyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is halogen with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is –OH with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is optionally substituted $-O-C_1-C_4$ alkyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is $-OCF_3$ with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is optionally substituted $-S-C_1-C_4$ alkyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In another aspect, each R^a is $-NR^bR^c$ with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom. In a further aspect, each R^a is optionally substituted $-C_2-C_4$ alkenyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or

attached via a carbon atom. In another aspect, each R^a is optionally substituted $-C_2-C_4$ alkynyl with the proviso that when one R^a is attached to C through an O, S, or N atom, then the other R^a attached to the same C is a hydrogen, or attached via a carbon atom.

In one aspect, R^b is hydrogen. In an additional aspect, R^b is optionally substituted $-C_1-C_4$ alkyl.

In one aspect, R^c is hydrogen. In another aspect, R^c is optionally substituted $-C_1-C_4$ alkyl. In a further aspect, R^c is optionally substituted $-C(O)-C_1-C_4$ alkyl. In yet another aspect, R^c is -C(O)H.

In a further aspect, R^1 and R^2 are the same and are selected from the group consisting of halogen, $-C_1-C_4$ alkyl, $-CF_3$, and cyano. In yet another aspect, R^1 and R^2 are different and are selected from the group consisting of halogen, $-C_1-C_4$ alkyl, $-CF_3$, and cyano. In an additional aspect, R^1 and R^2 are each halogen. In another aspect, R^1, R^2, R^6, R^7, R^8, and R^9 are each optionally substituted $-C_1-C_4$ alkyl. In a further aspect, R^1, R^2, R^6, R^7, R^8, and R^9 are each optionally substituted $-S-C_1-C_3$ alkyl. In another aspect, R^1, R^2, R^6, R^7, R^8, and R^9 are each optionally substituted $-C_2-C_4$ alkenyl. In a further aspect, R^1, R^2, R^6, R^7, R^8, and R^9 are each optionally substituted $-C_2-C_4$ alkynyl. In another aspect, R^1, R^2, R^6, R^7, R^8, and R^9 are each $-CF_3$. In a further aspect, R^1, R^2, R^6, R^7, R^8, and R^9 are each $-OCF_3$. In another aspect, R^1, R^2, R^6, R^7, R^8, and R^9 are each optionally substituted-$O-C_1-C_3$ alkyl. In a further aspect, R^1, R^2, R^6, R^7, R^8, and R^9 are each cyano.

In one aspect, R^6 and T are taken together along with the carbons they are attached to form a ring of 5 to 6 atoms containing 0 to 2 unsaturations and 0 to 2 heteroatoms independently selected from $-NR^i-$, -O-, and -S- with the proviso that when there are 2 heteroatoms in the ring and both heteroatoms are different than nitrogen then both heteroatoms have to be separated by at least one carbon atom; and X is attached to this ring to either a carbon or a nitrogen by either $-(CR^a_2)-$ or -C(O)- or a bond if X is attached directly to a carbon atom. In one aspect, R^6 and T are taken together along with the carbons they are attached to form a ring of 5 to 6 atoms containing 0 unsaturations. In another aspect, R^6 and T are taken together along with the carbons they are attached to form a ring of 5 to 6 atoms containing 1 unsaturation. R^6 and T are taken together along with the carbons they are attached to form a ring of 5 to 6 atoms containing 2 unsaturations. In one aspect, 0 to 2 heteroatoms are $-NR^i-$. In another aspect, 0 to 2 heteroatoms are -O-. In another aspect, 0 to 2 heteroatoms are -S-.

In one aspect, R^i is hydrogen. In another aspect, R^i is $-C(O)C_1-C_4$ alkyl. In another aspect, R^i is $-C_1-C_4$ alkyl. In a further aspect, R^i is $-C_1-C_4$-aryl.

In yet another aspect, R^3 and R^4 are each hydrogen. In another aspect, R^3 and R^4 are each halogen. In a further aspect, R^3 and R^4 are each $-CF_3$. In another aspect, R^3 and R^4 are each $-OCF_3$. In a further aspect, R^3 and R^4 are each cyano. In another aspect, R^3 and R^4 are each optionally substituted $-C_1-C_{12}$ alkyl. In a further aspect, R^3 and R^4 are each optionally substituted $-C_2-C_{12}$ alkenyl. In another aspect, R^3 and R^4 are each optionally substituted $-C_2-C_{12}$ alkynyl. In a further aspect, R^3 and R^4 are each optionally substituted $-(CR^a{}_2)_m$aryl. In another aspect, R^3 and R^4 are each optionally substituted $-(CR^a{}_2)_m$cycloalkyl. In a further aspect, R^3 and R^4 are each optionally substituted $-(CR^a{}_2)_m$heterocycloalkyl. In another aspect, R^3 and R^4 are each $-OR^d$. In another aspect, R^3 and R^4 are each $-SR^d$. In a further aspect, R^3 and R^4 are each $-S(=O)R^e$. In another aspect, R^3 and R^4 are each $-S(=O)_2R^e$. In a further aspect, R^3 and R^4 are each $-S(=O)_2NR^fR^g$. In another aspect, R^3 and R^4 are each $-C(O)NR^fR^g$. In a further aspect, R^3 and R^4 are each $-C(O)OR^h$. In another aspect, R^3 and R^4 are each $-C(O)R^e$. In afurther aspect, R^3 and R^4 are each $-N(R^b)C(O)R^e$. In another aspect, R^3 and R^4 are each $-N(R^b)C(O)NR^fR^g$. In a further aspect, R^3 and R^4 are each $-N(R^b)S(=O)_2R^e$. In another aspect, R^3 and R^4 are each $-N(R^b)S(=O)_2NR^fR^g$. In a further aspect, R^3 and R^4 are each $-NR^fR^g$.

In another aspect, R^4 is selected from the group consisting of hydrogen, halogen, $-C_1-C_4$ alkyl, cyano and CF_3. In a further aspect, R^3 is selected from the group consisting of halogen, optionally substituted $-C_1-C_6$ alkyl, $-CF_3$, cyano, $-C(O)NR^fR^g$, optionally substituted $-(CR^a{}_2)_n$aryl, $-SO_2NR^fR^g$, and $-SO_2R^e$.

In another aspect, each R^d is optionally substituted $-C_1-C_{12}$ alkyl. In a further aspect, each R^d is optionally substituted $-C_2-C_{12}$ alkenyl. In another aspect, each R^d is optionally substituted $-C_2-C_{12}$ alkynyl. In a further aspect, each R^d is optionally substituted $-(CR^b{}_2)_n$aryl. In another aspect, each R^d is optionally substituted $-(CR^b{}_2)_n$cycloalkyl. In a further aspect, each R^d is optionally substituted $-(CR^b{}_2)_n$heterocycloalkyl. In another aspect, each R^d is $-C(O)NR^fR^g$.

In an additional aspect, R^e is optionally substituted $-C_1-C_{12}$ alkyl. In another aspect, R^e is optionally substituted $-C_2-C_{12}$ alkenyl. In a further aspect, R^e is optionally substituted $-C_2-C_{12}$ alkynyl. In another aspect, R^e is optionally substituted $-(CR^a{}_2)_n$aryl. In a further aspect, R^e is optionally substituted $-(CR^a{}_2)_n$cycloalkyl. In another aspect, R^e is optionally substituted $-(CR^a{}_2)_n$heterocycloalkyl.

In one aspect, R^f and R^g are each hydrogen. In an additional aspect, R^f and R^g are each optionally substituted -C_1-C_{12} alkyl. In another aspect, R^f and R^g are each optionally substituted -C_2-C_{12} alkenyl. In an additional aspect, R^f and R^g are each optionally substituted -C_2-C_{12} alkynyl. In a further aspect, R^f and R^g are each optionally substituted -$(CR^b{}_2)_n$aryl. In an additional aspect, R^f and R^g are each optionally substituted -$(CR^b{}_2)_n$cycloalkyl. In another aspect, R^f and R^g are each optionally substituted -$(CR^b{}_2)_n$heterocycloalkyl.

In an additional aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup which is O. In another aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup which is NR^c. In another aspect, R^f and R^g may together form an optionally substituted heterocyclic ring, which may contain a second heterogroup which is S. In one aspect, R^f and R^g may together form an unsubstituted heterocyclic ring, which may contain a second heterogroup. In another aspect, the optionally substituted heterocyclic ring may be substituted with 1 substituent selected from the group consisting of optionally substituted -C_1-C_4 alkyl, -OR^b, oxo, cyano, -CF_3, optionally substituted phenyl, and -$C(O)OR^h$. In further aspect, the optionally substituted heterocyclic ring may be substituted with 2 substituents selected from the group consisting of optionally substituted -C_1-C_4 alkyl, -OR^b, oxo, cyano, -CF_3, optionally substituted phenyl, and -$C(O)OR^h$. In another aspect, the optionally substituted heterocyclic ring may be substituted with 3 substituents selected from the group consisting of optionally substituted -C_1-C_4 alkyl, -OR^b, oxo, cyano, -CF_3, optionally substituted phenyl, and -$C(O)OR^h$. In a further aspect, the optionally substituted heterocyclic ring may be substituted with 4 substituents selected from the group consisting of optionally substituted -C_1-C_4 alkyl, -OR^b, oxo, cyano, -CF_3, optionally substituted phenyl, and -$C(O)OR^h$.

In a further aspect, R^h is optionally substituted -C_1-C_{12} alkyl. In another aspect, R^h is optionally substituted -C_2-C_{12} alkenyl. In a further aspect, R^h is optionally substituted -C_2-C_{12} alkynyl. In another aspect, R^h is optionally substituted -$(CR^b{}_2)_n$aryl. In a further aspect, R^h is optionally substituted -$(CR^b{}_2)_n$cycloalkyl. In another aspect, R^h is optionally substituted -$(CR^b{}_2)_n$heterocycloalkyl.

In one aspect, R^5 is selected from the group consisting of -OH, -$OC(O)R^e$, -$OC(O)OR^h$, -F, and -$NHC(O)R^e$. In an additional aspect, R^5 is optionally substituted -OC_1-C_6 alkyl. In another aspect, R^5 is -$OC(O)R^e$. In a further aspect, R^5 is -

$OC(O)OR^h$. In another aspect, R^5 is –F. In another aspect, R^5 is $-NHC(O)R^e$. In a further aspect, R^5 is $-NHS(=O)R^e$. In another aspect, R^5 is $-NHS(=O)_2R^e$. In a further aspect, R^5 is

$-NHC(=S)NH(R^h)$. In another aspect, R^5 is $-NHC(O)NH(R^h)$.

Each of the individual species of compounds of Formula III which can be generated by making all of the above permutations may be specifically set forth as for inclusion or specifically may be excluded from the present invention.

In an additional aspect, this invention relates to Formulas I, II, III, or VIII wherein X is $P(O)YR^{11}Y'R^{11}$.

In one aspect, Y and Y' are each independently selected from the group consisting of -O-, and $-NR^v-$. In another aspect, Y and Y' are each independently selected from the group consisting of -O-, and $-NR^v-$; when Y and Y' are -O- , R^{11} attached to -O- is -H, alkyl. In another aspect, Y and Y' are each independently selected from the group consisting of -O-, and $-NR^v-$; when Y and Y' are -O- , R^{11} attached to -O- is optionally substituted aryl. In another aspect, Y and Y' are each independently selected from the group consisting of -O-, and $-NR^v-$; when Y and Y' are -O- , R^{11} attached to -O- is optionally substituted heterocycloalkyl . In a further aspect, Y and Y' are each independently selected from the group consisting of -O-, and $-NR^v-$; when Y and Y' are -O- , R^{11} attached to -O- is optionally substituted CH_2-heterocycloakyl. In one aspect, the cyclic moiety contains a carbonate or thiocarbonate. In another aspect, the cyclic moiety contains optionally substituted –alkylaryl. In another aspect, the cyclic moiety contains a $-C(R^z)_2OC(O)NR^z_2$. In another aspect, the cyclic moiety contains $-NR^z-C(O)-R^y$. In another aspect, the cyclic moiety contains $-C(R^z)_2-OC(O)R^y$. In another aspect, the cyclic moiety contains $-C(R^z)_2-O-C(O)OR^y$. In a further aspect, the cyclic moiety contains $-C(R^z)_2OC(O)SR^y$. In another aspect, the cyclic moiety contains -alkyl-S-C(O)R^y. In another aspect, the cyclic moiety contains -alkyl-S-S-alkylhydroxy. In a further aspect, the cyclic moiety contains -alkyl-S-S-S-alkylhydroxy.

In yet another aspect, Y and Y' are $-NR^v-$. In another aspect, when Y and Y' are $-NR^v-$, then R^{11} attached to $-NR^v-$ is –H. In a further aspect, when Y and Y' are $-NR^v-$, then R^{11} attached to $-NR^v-$ is $-[C(R^z)_2]_q-COOR^y$. In another aspect, when Y and Y' are $-NR^v-$, then R^{11} attached to $-NR^v-$ is $-C(R^x)_2COOR^y$. In a further aspect,

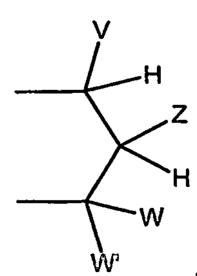
when Y and Y' are -NR^{v}-, then R^{11} attached to -NR^{v}- is -[C(R^{z})$_2$]$_q$-C(O)SR^{y}. In another aspect, when Y and Y' are -NR^{v}-, then R^{11} attached to -NR^{v}- is -cycloalkylene-COOR^{y}.

In one aspect, Y is -O- and Y' is NR^{v}. In another aspect, when Y is -O- and Y' is NR^{v}, then R^{11} attached to -O- is –H. In a further aspect, when Y is -O- and Y' is NR^{v}, then R^{11} attached to -O- is alkyl. In another aspect, when Y is -O- and Y' is NR^{v}, then R^{11} attached to -O- is optionally substituted aryl. In a further aspect, when Y is -O- and Y' is NR^{v}, then R^{11} attached to -O- is optionally substituted heterocycloalkyl. In another aspect, when Y is -O- and Y' is NR^{v}, then R^{11} attached to -O- is optionally substituted CH$_2$-heterocycloakyl. In one aspect, the cyclic moiety contains a carbonate or thiocarbonate. In another aspect, the cyclic moiety contains optionally substituted –alkylaryl. In another aspect, the cyclic moiety contains -C(R^{z})$_2$OC(O)NR^{z}$_2$. In another aspect, the cyclic moiety contains -NR^{z}-C(O)-R^{y}. In another aspect, the cyclic moiety contains -C(R^{z})$_2$- OC(O)R^{y}. In another aspect, the cyclic moiety contains -C(R^{z})$_2$-O-C(O)OR^{y}. In a further aspect, the cyclic moiety contains -C(R^{z})$_2$OC(O)SR^{y}. In another aspect, the cyclic moiety contains -alkyl-S-C(O)R^{y}. In another aspect, the cyclic moiety contains -alkyl-S-S-alkylhydroxy. In a further aspect, the cyclic moiety contains -alkyl-S-S-S-alkylhydroxy.

In another aspect, when Y is -O- and Y' is NR^{v}, and R^{11} attached to -NR^{v}- is –H. In a further aspect, when Y is -O- and Y' is NR^{v}, and R^{11} attached to -NR^{v}- is -[C(R^{z})$_2$]$_q$-COOR^{y}. In another aspect, when Y is -O- and Y' is NR^{v}, and R^{11} attached to -NR^{v}- is -C(R^{x})$_2$COOR^{y}. In a further aspect, when Y is -O- and Y' is NR^{v}, and R^{11} attached to -NR^{v}- is -[C(R^{z})$_2$]$_q$-C(O)SR^{y}. In another aspect, when Y is -O- and Y' is NR^{v}, and R^{11} attached to -NR^{v}- is -cycloalkylene-COOR^{y}.

In another aspect, Y and Y' are independently selected from -O- and -NR^{v}-, then together R^{11} and R^{11} are -alkyl-S-S-alkyl- to form a cyclic group.

In one aspect, Y and Y' are independently selected from -O- and -NR^{v}- and together R^{11} and R^{11} are the group:



In a further aspect, V is hydrogen. In another aspect, V is optionally substituted alkyl. In a further aspect, V is optionally substituted aralkyl. In another aspect, V is heterocycloalkyl. In another aspect, V is aryl. In a further aspect, V is substituted aryl. In another aspect, V is heteroaryl. In a further aspect, V is substituted heteroaryl. In another aspect, V is optionally substituted 1-alkenyl. In a further aspect,V is optionally substituted 1-alkynyl.

In a further aspect, W is hydrogen. In another aspect, W is optionally substituted alkyl. In a further aspect, W is optionally substituted aralkyl. In another aspect, W is heterocycloalkyl. In another aspect, W is aryl. In a further aspect, W is substituted aryl. In another aspect, W is heteroaryl. In a further aspect, W is substituted heteroaryl. In another aspect, W is optionally substituted 1-alkenyl. In a further aspect,W is optionally substituted 1-alkynyl.

In a further aspect, W' is hydrogen. In another aspect, W' is optionally substituted alkyl. In a further aspect, W' is optionally substituted aralkyl. In another aspect, W' is heterocycloalkyl. In another aspect, W' is aryl. In a further aspect, W' is substituted aryl. In another aspect, W' is heteroaryl. In a further aspect, W' is substituted heteroaryl. In another aspect, W' is optionally substituted 1-alkenyl. In a further aspect, W' is optionally substituted 1-alkynyl.

In one aspect, together V and Z are connected via an additional 3-5 atoms to form a cyclic group containing 5-7 atoms, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon. In one aspect, the ring is substituted with hydroxyl attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus. In another aspect, the ring is substituted with acyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus. In a further aspect, the ring is substituted with alkylthiocarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus. In another aspect, the ring is substituted with alkoxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus. In a further aspect, the ring is substituted with aryloxycarbonyloxy attached to a carbon atom that is three atoms from both Y groups attached to the phosphorus.

In yet another aspect, together V and Z are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, that is fused to an aryl group at the beta and gamma position to the Y attached to the phosphorus.

In a further aspect, together V and W are connected via an additional 3 carbon atoms to form an optionally substituted cyclic group containing 6 carbon atoms and substituted with one substituent. In one aspect, the substituent is hydroxyl that is attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus. In another aspect, the substituent is acyloxy that is attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus. In another aspect, the substituent is alkoxycarbonyloxy that is attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus. In another aspect, the substituent is alkylthiocarbonyloxy that is attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus. In another aspect, the substituent is aryloxycarbonyloxy that is attached to one of said carbon atoms that is three atoms from a Y attached to the phosphorus.

In another aspect, together Z and W are connected via an additional 3-5 atoms to form a cyclic group, wherein 0–1 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl.

In yet another aspect, together W and W' are connected via an additional 2-5 atoms to form a cyclic group, wherein 0–2 atoms are heteroatoms and the remaining atoms are carbon, and V must be aryl, substituted aryl, heteroaryl, or substituted heteroaryl.

In one aspect, Z is $-CHR^zOH$. In another aspect, Z is $-CHR^zOC(O)R^y$. In a further aspect, Z is $-CHR^zOC(S)R^y$. In another aspect, Z is $-CHR^zOC(S)OR^y$. In a further aspect, Z is $-CHR^zOC(O)SR^y$. In another aspect, Z is $-CHR^zOCO_2R^y$. In a further aspect, Z is $-OR^z$. In another aspect, Z is $-SR^z$. In a further aspect, Z is $-CHR^zN_3$. In another aspect, Z is $-CH_2aryl$. In a further aspect, Z is -CH(aryl)OH. In another aspect, Z is $-CH(CH{=}CR^z_2)OH$. In another aspect, Z is $-CH(C{\equiv}CR^z)OH$. In a further aspect, Z is $-R^z$. In another aspect, Z is $-NR^z_2$. In a further aspect, Z is $-OCOR^y$. In another aspect, Z is $-OCO_2R^y$. In a further aspect, Z is $-SCOR^y$. In another aspect, Z is $-SCO_2R^y$. In a further aspect, Z is $-NHCOR^z$. In another aspect, Z is $-NHCO_2R^y$. In a further aspect, Z is $-CH_2NHaryl$. In another aspect, Z is $-(CH_2)_q-OR^z$. In a further aspect, Z is $-(CH_2)_q-SR^z$.

In one aspect R^{11} is not hydrogen. In one aspect, q is 2. In a further aspect, q is 3.

In one aspect, R^y is alkyl. In another aspect, R^y is aryl. In a further aspect, R^y is heterocycloalkyl. In another aspect, R^y is aralkyl.

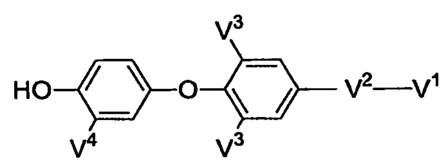
In one aspect, R^x is –H. In another aspect, R^x is alkyl. In yet another aspect, together R^x and R^x form a cyclic alkyl group.

In one aspect, R^v is –H. In another aspect, R^v is lower alkyl. In another aspect, R^v is acyloxyalkyl. In another aspect, R^v is alkoxycarbonyloxyalkyl. In another aspect, R^v is lower acyl.

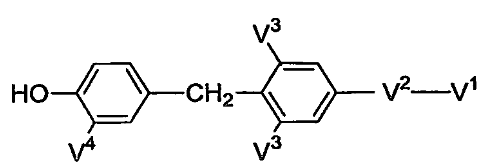
In one aspect, the present invention excludes throughout unsubstituted lower alkyl diesters of X when X is PO_3H_2, *e.g.*, where X is $-P(O)(OCH_2CH_3)_2$.

SPECIFIC COMPOUNDS

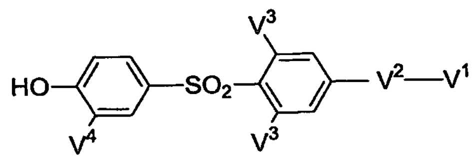
In one aspect the following compounds are included in the invention but the compounds are not limited to these illustrative compounds. The compounds are shown without depiction of stereochemistry since the compounds are biologically active as the diastereomeric mixture or as a single stereoisomer. Compounds named in Table 2 are designated by numbers assigned to the variables of formulas V-VII using the following convention: $V^1.V^2.V^3.V^4$.



Formula V



Formula VI



Formula VII

Variable V^1:

1) $-P(O)(OH)_2$
2) $-P(O)[O-CH_2OC(O)C(CH_3)_3]_2$
3) $-P(O)[O-CH_2OC(O)CH(CH_3)_2]_2$
4) $-P(O)[O-CH_2OC(O)OCH_2CH_3]_2$
5) $-P(O)[NH-CH(CH_3)C(O)OCH_2CH_3]_2$
6) $-P(O)[NH-C(CH_3)_2C(O)OCH_2CH_3]_2$
7) $-P(O)(OC_6H_5)_2$
8) $-P(O)(O-CH(3\text{-chlorophenyl})CH_2CH_2-O)$
9) $-P(O)(O-CH(4\text{-pyridyl})CH_2CH_2-O)$

Variable V^2:

1) $-CH_2-$
2) $-OCH_2-$
3) $-CH_2-CH_2-$
4) $-NHCH_2-$
5) $-NH(CO)-$
6) $-CH_2-CH(NH_2)-$ (*R*-configuration)
7) $-CH_2-CH(NH_2)-$ (*S*-configuration)
8) -CH=CH- (*trans*)
9) - null

Variable V^3:

1) -Omethyl
2) iodo
3) bromo
4) chloro
5) fluoro
6) methyl

7) trifluoromethyl

8) cyano

9) $-OCF_3$

Variable V^4:

1) iodo

2) $CH(CH_3)_2$

3) C_6H_{11}

4) C_6H_5

5) $-C(O)NHC_6H_{11}$

6) -CH(OH)(4-fluorophenyl)

7) $-SO_2$(4-fluorophenyl)

8) $-SO_2$(*N*-piperazinyl)

9) bromo

In another aspect additional compounds are listed in Table 2 using Formula V, VI or VII. For example, the compound 1.3.6.7 from Formula V represents the compound of Formula V wherein V^1 is 1, *i.e.*, of group V^1 is 1, *i.e.*, of group $-P(O)(OH)_2$; V^2 is 3, *i.e.*, of group $-CH_2-CH_2-$; V^3 is 6, *i.e.*, of group methyl; and V^4 is 7, *i.e.*, of group $-SO_2$(4-fluorophenyl).

TABLE 2

1.1.1.1	1.1.1.2	1.1.1.3	1.1.1.4	1.1.1.5	1.1.1.6	1.1.1.7	1.1.1.8	1.1.1.9	1.1.2.1
1.1.2.2	1.1.2.3	1.1.2.4	1.1.2.5	1.1.2.6	1.1.2.7	1.1.2.8	1.1.2.9	1.1.3.1	1.1.3.2
1.1.3.3	1.1.3.4	1.1.3.5	1.1.3.6	1.1.3.7	1.1.3.8	1.1.3.9	1.1.4.1	1.1.4.2	1.1.4.3
1.1.4.4	1.1.4.5	1.1.4.6	1.1.4.7	1.1.4.8	1.1.4.9	1.1.5.1	1.1.5.2	1.1.5.3	1.1.5.4
1.1.5.5	1.1.5.6	1.1.5.7	1.1.5.8	1.1.5.9	1.1.6.1	1.1.6.2	1.1.6.3	1.1.6.4	1.1.6.5
1.1.6.6	1.1.6.7	1.1.6.8	1.1.6.9	1.1.7.1	1.1.7.2	1.1.7.3	1.1.7.4	1.1.7.5	1.1.7.6
1.1.7.7	1.1.7.8	1.1.7.9	1.1.8.1	1.1.8.2	1.1.8.3	1.1.8.4	1.1.8.5	1.1.8.6	1.1.8.7
1.1.8.8	1.1.8.9	1.1.9.1	1.1.9.2	1.1.9.3	1.1.9.4	1.1.9.5	1.1.9.6	1.1.9.7	1.1.9.8
1.1.9.9	1.2.1.1	1.2.1.2	1.2.1.3	1.2.1.4	1.2.1.5	1.2.1.6	1.2.1.7	1.2.1.8	1.2.1.9
1.2.2.1	1.2.2.2	1.2.2.3	1.2.2.4	1.2.2.5	1.2.2.6	1.2.2.7	1.2.2.8	1.2.2.9	1.2.3.1
1.2.3.2	1.2.3.3	1.2.3.4	1.2.3.5	1.2.3.6	1.2.3.7	1.2.3.8	1.2.3.9	1.2.4.1	1.2.4.2
1.2.4.3	1.2.4.4	1.2.4.5	1.2.4.6	1.2.4.7	1.2.4.8	1.2.4.9	1.2.5.1	1.2.5.2	1.2.5.3
1.2.5.4	1.2.5.5	1.2.5.6	1.2.5.7	1.2.5.8	1.2.5.9	1.2.6.1	1.2.6.2	1.2.6.3	1.2.6.4
1.2.6.5	1.2.6.6	1.2.6.7	1.2.6.8	1.2.6.9	1.2.7.1	1.2.7.2	1.2.7.3	1.2.7.4	1.2.7.5
1.2.7.6	1.2.7.7	1.2.7.8	1.2.7.9	1.2.8.1	1.2.8.2	1.2.8.3	1.2.8.4	1.2.8.5	1.2.8.6
1.2.8.7	1.2.8.8	1.2.8.9	1.2.9.1	1.2.9.2	1.2.9.3	1.2.9.4	1.2.9.5	1.2.9.6	1.2.9.7
1.2.9.8	1.2.9.9	1.3.1.1	1.3.1.2	1.3.1.3	1.3.1.4	1.3.1.5	1.3.1.6	1.3.1.7	1.3.1.8
1.3.1.9	1.3.2.1	1.3.2.2	1.3.2.3	1.3.2.4	1.3.2.5	1.3.2.6	1.3.2.7	1.3.2.8	1.3.2.9
1.3.3.1	1.3.3.2	1.3.3.3	1.3.3.4	1.3.3.5	1.3.3.6	1.3.3.7	1.3.3.8	1.3.3.9	1.3.4.1
1.3.4.2	1.3.4.3	1.3.4.4	1.3.4.5	1.3.4.6	1.3.4.7	1.3.4.8	1.3.4.9	1.3.5.1	1.3.5.2
1.3.5.3	1.3.5.4	1.3.5.5	1.3.5.6	1.3.5.7	1.3.5.8	1.3.5.9	1.3.6.1	1.3.6.2	1.3.6.3
1.3.6.4	1.3.6.5	1.3.6.6	1.3.6.7	1.3.6.8	1.3.6.9	1.3.7.1	1.3.7.2	1.3.7.3	1.3.7.4
1.3.7.5	1.3.7.6	1.3.7.7	1.3.7.8	1.3.7.9	1.3.8.1	1.3.8.2	1.3.8.3	1.3.8.4	1.3.8.5
1.3.8.6	1.3.8.7	1.3.8.8	1.3.8.9	1.3.9.1	1.3.9.2	1.3.9.3	1.3.9.4	1.3.9.5	1.3.9.6
1.3.9.7	1.3.9.8	1.3.9.9	1.4.1.1	1.4.1.2	1.4.1.3	1.4.1.4	1.4.1.5	1.4.1.6	1.4.1.7
1.4.1.8	1.4.1.9	1.4.2.1	1.4.2.2	1.4.2.3	1.4.2.4	1.4.2.5	1.4.2.6	1.4.2.7	1.4.2.8
1.4.2.9	1.4.3.1	1.4.3.2	1.4.3.3	1.4.3.4	1.4.3.5	1.4.3.6	1.4.3.7	1.4.3.8	1.4.3.9
1.4.4.1	1.4.4.2	1.4.4.3	1.4.4.4	1.4.4.5	1.4.4.6	1.4.4.7	1.4.4.8	1.4.4.9	1.4.5.1
1.4.5.2	1.4.5.3	1.4.5.4	1.4.5.5	1.4.5.6	1.4.5.7	1.4.5.8	1.4.5.9	1.4.6.1	1.4.6.2
1.4.6.3	1.4.6.4	1.4.6.5	1.4.6.6	1.4.6.7	1.4.6.8	1.4.6.9	1.4.7.1	1.4.7.2	1.4.7.3
1.4.7.4	1.4.7.5	1.4.7.6	1.4.7.7	1.4.7.8	1.4.7.9	1.4.8.1	1.4.8.2	1.4.8.3	1.4.8.4
1.4.8.5	1.4.8.6	1.4.8.7	1.4.8.8	1.4.8.9	1.4.9.1	1.4.9.2	1.4.9.3	1.4.9.4	1.4.9.5
1.4.9.6	1.4.9.7	1.4.9.8	1.4.9.9	1.5.1.1	1.5.1.2	1.5.1.3	1.5.1.4	1.5.1.5	1.5.1.6
1.5.1.7	1.5.1.8	1.5.1.9	1.5.2.1	1.5.2.2	1.5.2.3	1.5.2.4	1.5.2.5	1.5.2.6	1.5.2.7
1.5.2.8	1.5.2.9	1.5.3.1	1.5.3.2	1.5.3.3	1.5.3.4	1.5.3.5	1.5.3.6	1.5.3.7	1.5.3.8
1.5.3.9	1.5.4.1	1.5.4.2	1.5.4.3	1.5.4.4	1.5.4.5	1.5.4.6	1.5.4.7	1.5.4.8	1.5.4.9
1.5.5.1	1.5.5.2	1.5.5.3	1.5.5.4	1.5.5.5	1.5.5.6	1.5.5.7	1.5.5.8	1.5.5.9	1.5.6.1
1.5.6.2	1.5.6.3	1.5.6.4	1.5.6.5	1.5.6.6	1.5.6.7	1.5.6.8	1.5.6.9	1.5.7.1	1.5.7.2
1.5.7.3	1.5.7.4	1.5.7.5	1.5.7.6	1.5.7.7	1.5.7.8	1.5.7.9	1.5.8.1	1.5.8.2	1.5.8.3
1.5.8.4	1.5.8.5	1.5.8.6	1.5.8.7	1.5.8.8	1.5.8.9	1.5.9.1	1.5.9.2	1.5.9.3	1.5.9.4
1.5.9.5	1.5.9.6	1.5.9.7	1.5.9.8	1.5.9.9	1.6.1.1	1.6.1.2	1.6.1.3	1.6.1.4	1.6.1.5
1.6.1.6	1.6.1.7	1.6.1.8	1.6.1.9	1.6.2.1	1.6.2.2	1.6.2.3	1.6.2.4	1.6.2.5	1.6.2.6
1.6.2.7	1.6.2.8	1.6.2.9	1.6.3.1	1.6.3.2	1.6.3.3	1.6.3.4	1.6.3.5	1.6.3.6	1.6.3.7
1.6.3.8	1.6.3.9	1.6.4.1	1.6.4.2	1.6.4.3	1.6.4.4	1.6.4.5	1.6.4.6	1.6.4.7	1.6.4.8
1.6.4.9	1.6.5.1	1.6.5.2	1.6.5.3	1.6.5.4	1.6.5.5	1.6.5.6	1.6.5.7	1.6.5.8	1.6.5.9
1.6.6.1	1.6.6.2	1.6.6.3	1.6.6.4	1.6.6.5	1.6.6.6	1.6.6.7	1.6.6.8	1.6.6.9	1.6.7.1
1.6.7.2	1.6.7.3	1.6.7.4	1.6.7.5	1.6.7.6	1.6.7.7	1.6.7.8	1.6.7.9	1.6.8.1	1.6.8.2
1.6.8.3	1.6.8.4	1.6.8.5	1.6.8.6	1.6.8.7	1.6.8.8	1.6.8.9	1.6.9.1	1.6.9.2	1.6.9.3

Table 2 - continued

1.6.9.4	1.6.9.5	1.6.9.6	1.6.9.7	1.6.9.8	1.6.9.9	1.7.1.1	1.7.1.2	1.7.1.3	1.7.1.4
1.7.1.5	1.7.1.6	1.7.1.7	1.7.1.8	1.7.1.9	1.7.2.1	1.7.2.2	1.7.2.3	1.7.2.4	1.7.2.5
1.7.2.6	1.7.2.7	1.7.2.8	1.7.2.9	1.7.3.1	1.7.3.2	1.7.3.3	1.7.3.4	1.7.3.5	1.7.3.6
1.7.3.7	1.7.3.8	1.7.3.9	1.7.4.1	1.7.4.2	1.7.4.3	1.7.4.4	1.7.4.5	1.7.4.6	1.7.4.7
1.7.4.8	1.7.4.9	1.7.5.1	1.7.5.2	1.7.5.3	1.7.5.4	1.7.5.5	1.7.5.6	1.7.5.7	1.7.5.8
1.7.5.9	1.7.6.1	1.7.6.2	1.7.6.3	1.7.6.4	1.7.6.5	1.7.6.6	1.7.6.7	1.7.6.8	1.7.6.9
1.7.7.1	1.7.7.2	1.7.7.3	1.7.7.4	1.7.7.5	1.7.7.6	1.7.7.7	1.7.7.8	1.7.7.9	1.7.8.1
1.7.8.2	1.7.8.3	1.7.8.4	1.7.8.5	1.7.8.6	1.7.8.7	1.7.8.8	1.7.8.9	1.7.9.1	1.7.9.2
1.7.9.3	1.7.9.4	1.7.9.5	1.7.9.6	1.7.9.7	1.7.9.8	1.7.9.9	1.8.1.1	1.8.1.2	1.8.1.3
1.8.1.4	1.8.1.5	1.8.1.6	1.8.1.7	1.8.1.8	1.8.1.9	1.8.2.1	1.8.2.2	1.8.2.3	1.8.2.4
1.8.2.5	1.8.2.6	1.8.2.7	1.8.2.8	1.8.2.9	1.8.3.1	1.8.3.2	1.8.3.3	1.8.3.4	1.8.3.5
1.8.3.6	1.8.3.7	1.8.3.8	1.8.3.9	1.8.4.1	1.8.4.2	1.8.4.3	1.8.4.4	1.8.4.5	1.8.4.6
1.8.4.7	1.8.4.8	1.8.4.9	1.8.5.1	1.8.5.2	1.8.5.3	1.8.5.4	1.8.5.5	1.8.5.6	1.8.5.7
1.8.5.8	1.8.5.9	1.8.6.1	1.8.6.2	1.8.6.3	1.8.6.4	1.8.6.5	1.8.6.6	1.8.6.7	1.8.6.8
1.8.6.9	1.8.7.1	1.8.7.2	1.8.7.3	1.8.7.4	1.8.7.5	1.8.7.6	1.8.7.7	1.8.7.8	1.8.7.9
1.8.8.1	1.8.8.2	1.8.8.3	1.8.8.4	1.8.8.5	1.8.8.6	1.8.8.7	1.8.8.8	1.8.8.9	1.8.9.1
1.8.9.2	1.8.9.3	1.8.9.4	1.8.9.5	1.8.9.6	1.8.9.7	1.8.9.8	1.8.9.9	1.9.1.1	1.9.1.2
1.9.1.3	1.9.1.4	1.9.1.5	1.9.1.6	1.9.1.7	1.9.1.8	1.9.1.9	1.9.2.1	1.9.2.2	1.9.2.3
1.9.2.4	1.9.2.5	1.9.2.6	1.9.2.7	1.9.2.8	1.9.2.9	1.9.3.1	1.9.3.2	1.9.3.3	1.9.3.4
1.9.3.5	1.9.3.6	1.9.3.7	1.9.3.8	1.9.3.9	1.9.4.1	1.9.4.2	1.9.4.3	1.9.4.4	1.9.4.5
1.9.4.6	1.9.4.7	1.9.4.8	1.9.4.9	1.9.5.1	1.9.5.2	1.9.5.3	1.9.5.4	1.9.5.5	1.9.5.6
1.9.5.7	1.9.5.8	1.9.5.9	1.9.6.1	1.9.6.2	1.9.6.3	1.9.6.4	1.9.6.5	1.9.6.6	1.9.6.7
1.9.6.8	1.9.6.9	1.9.7.1	1.9.7.2	1.9.7.3	1.9.7.4	1.9.7.5	1.9.7.6	1.9.7.7	1.9.7.8
1.9.7.9	1.9.8.1	1.9.8.2	1.9.8.3	1.9.8.4	1.9.8.5	1.9.8.6	1.9.8.7	1.9.8.8	1.9.8.9
1.9.9.1	1.9.9.2	1.9.9.3	1.9.9.4	1.9.9.5	1.9.9.6	1.9.9.7	1.9.9.8	1.9.9.9	2.1.1.1
2.1.1.2	2.1.1.3	2.1.1.4	2.1.1.5	2.1.1.6	2.1.1.7	2.1.1.8	2.1.1.9	2.1.2.1	2.1.2.2
2.1.2.3	2.1.2.4	2.1.2.5	2.1.2.6	2.1.2.7	2.1.2.8	2.1.2.9	2.1.3.1	2.1.3.2	2.1.3.3
2.1.3.4	2.1.3.5	2.1.3.6	2.1.3.7	2.1.3.8	2.1.3.9	2.1.4.1	2.1.4.2	2.1.4.3	2.1.4.4
2.1.4.5	2.1.4.6	2.1.4.7	2.1.4.8	2.1.4.9	2.1.5.1	2.1.5.2	2.1.5.3	2.1.5.4	2.1.5.5
2.1.5.6	2.1.5.7	2.1.5.8	2.1.5.9	2.1.6.1	2.1.6.2	2.1.6.3	2.1.6.4	2.1.6.5	2.1.6.6
2.1.6.7	2.1.6.8	2.1.6.9	2.1.7.1	2.1.7.2	2.1.7.3	2.1.7.4	2.1.7.5	2.1.7.6	2.1.7.7
2.1.7.8	2.1.7.9	2.1.8.1	2.1.8.2	2.1.8.3	2.1.8.4	2.1.8.5	2.1.8.6	2.1.8.7	2.1.8.8
2.1.8.9	2.1.9.1	2.1.9.2	2.1.9.3	2.1.9.4	2.1.9.5	2.1.9.6	2.1.9.7	2.1.9.8	2.1.9.9
2.2.1.1	2.2.1.2	2.2.1.3	2.2.1.4	2.2.1.5	2.2.1.6	2.2.1.7	2.2.1.8	2.2.1.9	2.2.2.1
2.2.2.2	2.2.2.3	2.2.2.4	2.2.2.5	2.2.2.6	2.2.2.7	2.2.2.8	2.2.2.9	2.2.3.1	2.2.3.2
2.2.3.3	2.2.3.4	2.2.3.5	2.2.3.6	2.2.3.7	2.2.3.8	2.2.3.9	2.2.4.1	2.2.4.2	2.2.4.3
2.2.4.4	2.2.4.5	2.2.4.6	2.2.4.7	2.2.4.8	2.2.4.9	2.2.5.1	2.2.5.2	2.2.5.3	2.2.5.4
2.2.5.5	2.2.5.6	2.2.5.7	2.2.5.8	2.2.5.9	2.2.6.1	2.2.6.2	2.2.6.3	2.2.6.4	2.2.6.5
2.2.6.6	2.2.6.7	2.2.6.8	2.2.6.9	2.2.7.1	2.2.7.2	2.2.7.3	2.2.7.4	2.2.7.5	2.2.7.6
2.2.7.7	2.2.7.8	2.2.7.9	2.2.8.1	2.2.8.2	2.2.8.3	2.2.8.4	2.2.8.5	2.2.8.6	2.2.8.7
2.2.8.8	2.2.8.9	2.2.9.1	2.2.9.2	2.2.9.3	2.2.9.4	2.2.9.5	2.2.9.6	2.2.9.7	2.2.9.8
2.2.9.9	2.3.1.1	2.3.1.2	2.3.1.3	2.3.1.4	2.3.1.5	2.3.1.6	2.3.1.7	2.3.1.8	2.3.1.9
2.3.2.1	2.3.2.2	2.3.2.3	2.3.2.4	2.3.2.5	2.3.2.6	2.3.2.7	2.3.2.8	2.3.2.9	2.3.3.1
2.3.3.2	2.3.3.3	2.3.3.4	2.3.3.5	2.3.3.6	2.3.3.7	2.3.3.8	2.3.3.9	2.3.4.1	2.3.4.2
2.3.4.3	2.3.4.4	2.3.4.5	2.3.4.6	2.3.4.7	2.3.4.8	2.3.4.9	2.3.5.1	2.3.5.2	2.3.5.3
2.3.5.4	2.3.5.5	2.3.5.6	2.3.5.7	2.3.5.8	2.3.5.9	2.3.6.1	2.3.6.2	2.3.6.3	2.3.6.4
2.3.6.5	2.3.6.6	2.3.6.7	2.3.6.8	2.3.6.9	2.3.7.1	2.3.7.2	2.3.7.3	2.3.7.4	2.3.7.5
2.3.7.6	2.3.7.7	2.3.7.8	2.3.7.9	2.3.8.1	2.3.8.2	2.3.8.3	2.3.8.4	2.3.8.5	2.3.8.6

Table 2 - continued

2.3.8.7	2.3.8.8	2.3.8.9	2.3.9.1	2.3.9.2	2.3.9.3	2.3.9.4	2.3.9.5	2.3.9.6	2.3.9.7
2.3.9.8	2.3.9.9	2.4.1.1	2.4.1.2	2.4.1.3	2.4.1.4	2.4.1.5	2.4.1.6	2.4.1.7	2.4.1.8
2.4.1.9	2.4.2.1	2.4.2.2	2.4.2.3	2.4.2.4	2.4.2.5	2.4.2.6	2.4.2.7	2.4.2.8	2.4.2.9
2.4.3.1	2.4.3.2	2.4.3.3	2.4.3.4	2.4.3.5	2.4.3.6	2.4.3.7	2.4.3.8	2.4.3.9	2.4.4.1
2.4.4.2	2.4.4.3	2.4.4.4	2.4.4.5	2.4.4.6	2.4.4.7	2.4.4.8	2.4.4.9	2.4.5.1	2.4.5.2
2.4.5.3	2.4.5.4	2.4.5.5	2.4.5.6	2.4.5.7	2.4.5.8	2.4.5.9	2.4.6.1	2.4.6.2	2.4.6.3
2.4.6.4	2.4.6.5	2.4.6.6	2.4.6.7	2.4.6.8	2.4.6.9	2.4.7.1	2.4.7.2	2.4.7.3	2.4.7.4
2.4.7.5	2.4.7.6	2.4.7.7	2.4.7.8	2.4.7.9	2.4.8.1	2.4.8.2	2.4.8.3	2.4.8.4	2.4.8.5
2.4.8.6	2.4.8.7	2.4.8.8	2.4.8.9	2.4.9.1	2.4.9.2	2.4.9.3	2.4.9.4	2.4.9.5	2.4.9.6
2.4.9.7	2.4.9.8	2.4.9.9	2.5.1.1	2.5.1.2	2.5.1.3	2.5.1.4	2.5.1.5	2.5.1.6	2.5.1.7
2.5.1.8	2.5.1.9	2.5.2.1	2.5.2.2	2.5.2.3	2.5.2.4	2.5.2.5	2.5.2.6	2.5.2.7	2.5.2.8
2.5.2.9	2.5.3.1	2.5.3.2	2.5.3.3	2.5.3.4	2.5.3.5	2.5.3.6	2.5.3.7	2.5.3.8	2.5.3.9
2.5.4.1	2.5.4.2	2.5.4.3	2.5.4.4	2.5.4.5	2.5.4.6	2.5.4.7	2.5.4.8	2.5.4.9	2.5.5.1
2.5.5.2	2.5.5.3	2.5.5.4	2.5.5.5	2.5.5.6	2.5.5.7	2.5.5.8	2.5.5.9	2.5.6.1	2.5.6.2
2.5.6.3	2.5.6.4	2.5.6.5	2.5.6.6	2.5.6.7	2.5.6.8	2.5.6.9	2.5.7.1	2.5.7.2	2.5.7.3
2.5.7.4	2.5.7.5	2.5.7.6	2.5.7.7	2.5.7.8	2.5.7.9	2.5.8.1	2.5.8.2	2.5.8.3	2.5.8.4
2.5.8.5	2.5.8.6	2.5.8.7	2.5.8.8	2.5.8.9	2.5.9.1	2.5.9.2	2.5.9.3	2.5.9.4	2.5.9.5
2.5.9.6	2.5.9.7	2.5.9.8	2.5.9.9	2.6.1.1	2.6.1.2	2.6.1.3	2.6.1.4	2.6.1.5	2.6.1.6
2.6.1.7	2.6.1.8	2.6.1.9	2.6.2.1	2.6.2.2	2.6.2.3	2.6.2.4	2.6.2.5	2.6.2.6	2.6.2.7
2.6.2.8	2.6.2.9	2.6.3.1	2.6.3.2	2.6.3.3	2.6.3.4	2.6.3.5	2.6.3.6	2.6.3.7	2.6.3.8
2.6.3.9	2.6.4.1	2.6.4.2	2.6.4.3	2.6.4.4	2.6.4.5	2.6.4.6	2.6.4.7	2.6.4.8	2.6.4.9
2.6.5.1	2.6.5.2	2.6.5.3	2.6.5.4	2.6.5.5	2.6.5.6	2.6.5.7	2.6.5.8	2.6.5.9	2.6.6.1
2.6.6.2	2.6.6.3	2.6.6.4	2.6.6.5	2.6.6.6	2.6.6.7	2.6.6.8	2.6.6.9	2.6.7.1	2.6.7.2
2.6.7.3	2.6.7.4	2.6.7.5	2.6.7.6	2.6.7.7	2.6.7.8	2.6.7.9	2.6.8.1	2.6.8.2	2.6.8.3
2.6.8.4	2.6.8.5	2.6.8.6	2.6.8.7	2.6.8.8	2.6.8.9	2.6.9.1	2.6.9.2	2.6.9.3	2.6.9.4
2.6.9.5	2.6.9.6	2.6.9.7	2.6.9.8	2.6.9.9	2.7.1.1	2.7.1.2	2.7.1.3	2.7.1.4	2.7.1.5
2.7.1.6	2.7.1.7	2.7.1.8	2.7.1.9	2.7.2.1	2.7.2.2	2.7.2.3	2.7.2.4	2.7.2.5	2.7.2.6
2.7.2.7	2.7.2.8	2.7.2.9	2.7.3.1	2.7.3.2	2.7.3.3	2.7.3.4	2.7.3.5	2.7.3.6	2.7.3.7
2.7.3.8	2.7.3.9	2.7.4.1	2.7.4.2	2.7.4.3	2.7.4.4	2.7.4.5	2.7.4.6	2.7.4.7	2.7.4.8
2.7.4.9	2.7.5.1	2.7.5.2	2.7.5.3	2.7.5.4	2.7.5.5	2.7.5.6	2.7.5.7	2.7.5.8	2.7.5.9
2.7.6.1	2.7.6.2	2.7.6.3	2.7.6.4	2.7.6.5	2.7.6.6	2.7.6.7	2.7.6.8	2.7.6.9	2.7.7.1
2.7.7.2	2.7.7.3	2.7.7.4	2.7.7.5	2.7.7.6	2.7.7.7	2.7.7.8	2.7.7.9	2.7.8.1	2.7.8.2
2.7.8.3	2.7.8.4	2.7.8.5	2.7.8.6	2.7.8.7	2.7.8.8	2.7.8.9	2.7.9.1	2.7.9.2	2.7.9.3
2.7.9.4	2.7.9.5	2.7.9.6	2.7.9.7	2.7.9.8	2.7.9.9	2.8.1.1	2.8.1.2	2.8.1.3	2.8.1.4
2.8.1.5	2.8.1.6	2.8.1.7	2.8.1.8	2.8.1.9	2.8.2.1	2.8.2.2	2.8.2.3	2.8.2.4	2.8.2.5
2.8.2.6	2.8.2.7	2.8.2.8	2.8.2.9	2.8.3.1	2.8.3.2	2.8.3.3	2.8.3.4	2.8.3.5	2.8.3.6
2.8.3.7	2.8.3.8	2.8.3.9	2.8.4.1	2.8.4.2	2.8.4.3	2.8.4.4	2.8.4.5	2.8.4.6	2.8.4.7
2.8.4.8	2.8.4.9	2.8.5.1	2.8.5.2	2.8.5.3	2.8.5.4	2.8.5.5	2.8.5.6	2.8.5.7	2.8.5.8
2.8.5.9	2.8.6.1	2.8.6.2	2.8.6.3	2.8.6.4	2.8.6.5	2.8.6.6	2.8.6.7	2.8.6.8	2.8.6.9
2.8.7.1	2.8.7.2	2.8.7.3	2.8.7.4	2.8.7.5	2.8.7.6	2.8.7.7	2.8.7.8	2.8.7.9	2.8.8.1
2.8.8.2	2.8.8.3	2.8.8.4	2.8.8.5	2.8.8.6	2.8.8.7	2.8.8.8	2.8.8.9	2.8.9.1	2.8.9.2
2.8.9.3	2.8.9.4	2.8.9.5	2.8.9.6	2.8.9.7	2.8.9.8	2.8.9.9	2.9.1.1	2.9.1.2	2.9.1.3
2.9.1.4	2.9.1.5	2.9.1.6	2.9.1.7	2.9.1.8	2.9.1.9	2.9.2.1	2.9.2.2	2.9.2.3	2.9.2.4
2.9.2.5	2.9.2.6	2.9.2.7	2.9.2.8	2.9.2.9	2.9.3.1	2.9.3.2	2.9.3.3	2.9.3.4	2.9.3.5
2.9.3.6	2.9.3.7	2.9.3.8	2.9.3.9	2.9.4.1	2.9.4.2	2.9.4.3	2.9.4.4	2.9.4.5	2.9.4.6
2.9.4.7	2.9.4.8	2.9.4.9	2.9.5.1	2.9.5.2	2.9.5.3	2.9.5.4	2.9.5.5	2.9.5.6	2.9.5.7
2.9.5.8	2.9.5.9	2.9.6.1	2.9.6.2	2.9.6.3	2.9.6.4	2.9.6.5	2.9.6.6	2.9.6.7	2.9.6.8
2.9.6.9	2.9.7.1	2.9.7.2	2.9.7.3	2.9.7.4	2.9.7.5	2.9.7.6	2.9.7.7	2.9.7.8	2.9.7.9

Table 2 - continued

2.9.8.1	2.9.8.2	2.9.8.3	2.9.8.4	2.9.8.5	2.9.8.6	2.9.8.7	2.9.8.8	2.9.8.9	2.9.9.1
2.9.9.2	2.9.9.3	2.9.9.4	2.9.9.5	2.9.9.6	2.9.9.7	2.9.9.8	2.9.9.9	3.1.1.1	3.1.1.2
3.1.1.3	3.1.1.4	3.1.1.5	3.1.1.6	3.1.1.7	3.1.1.8	3.1.1.9	3.1.2.1	3.1.2.2	3.1.2.3
3.1.2.4	3.1.2.5	3.1.2.6	3.1.2.7	3.1.2.8	3.1.2.9	3.1.3.1	3.1.3.2	3.1.3.3	3.1.3.4
3.1.3.5	3.1.3.6	3.1.3.7	3.1.3.8	3.1.3.9	3.1.4.1	3.1.4.2	3.1.4.3	3.1.4.4	3.1.4.5
3.1.4.6	3.1.4.7	3.1.4.8	3.1.4.9	3.1.5.1	3.1.5.2	3.1.5.3	3.1.5.4	3.1.5.5	3.1.5.6
3.1.5.7	3.1.5.8	3.1.5.9	3.1.6.1	3.1.6.2	3.1.6.3	3.1.6.4	3.1.6.5	3.1.6.6	3.1.6.7
3.1.6.8	3.1.6.9	3.1.7.1	3.1.7.2	3.1.7.3	3.1.7.4	3.1.7.5	3.1.7.6	3.1.7.7	3.1.7.8
3.1.7.9	3.1.8.1	3.1.8.2	3.1.8.3	3.1.8.4	3.1.8.5	3.1.8.6	3.1.8.7	3.1.8.8	3.1.8.9
3.1.9.1	3.1.9.2	3.1.9.3	3.1.9.4	3.1.9.5	3.1.9.6	3.1.9.7	3.1.9.8	3.1.9.9	3.2.1.1
3.2.1.2	3.2.1.3	3.2.1.4	3.2.1.5	3.2.1.6	3.2.1.7	3.2.1.8	3.2.1.9	3.2.2.1	3.2.2.2
3.2.2.3	3.2.2.4	3.2.2.5	3.2.2.6	3.2.2.7	3.2.2.8	3.2.2.9	3.2.3.1	3.2.3.2	3.2.3.3
3.2.3.4	3.2.3.5	3.2.3.6	3.2.3.7	3.2.3.8	3.2.3.9	3.2.4.1	3.2.4.2	3.2.4.3	3.2.4.4
3.2.4.5	3.2.4.6	3.2.4.7	3.2.4.8	3.2.4.9	3.2.5.1	3.2.5.2	3.2.5.3	3.2.5.4	3.2.5.5
3.2.5.6	3.2.5.7	3.2.5.8	3.2.5.9	3.2.6.1	3.2.6.2	3.2.6.3	3.2.6.4	3.2.6.5	3.2.6.6
3.2.6.7	3.2.6.8	3.2.6.9	3.2.7.1	3.2.7.2	3.2.7.3	3.2.7.4	3.2.7.5	3.2.7.6	3.2.7.7
3.2.7.8	3.2.7.9	3.2.8.1	3.2.8.2	3.2.8.3	3.2.8.4	3.2.8.5	3.2.8.6	3.2.8.7	3.2.8.8
3.2.8.9	3.2.9.1	3.2.9.2	3.2.9.3	3.2.9.4	3.2.9.5	3.2.9.6	3.2.9.7	3.2.9.8	3.2.9.9
3.3.1.1	3.3.1.2	3.3.1.3	3.3.1.4	3.3.1.5	3.3.1.6	3.3.1.7	3.3.1.8	3.3.1.9	3.3.2.1
3.3.2.2	3.3.2.3	3.3.2.4	3.3.2.5	3.3.2.6	3.3.2.7	3.3.2.8	3.3.2.9	3.3.3.1	3.3.3.2
3.3.3.3	3.3.3.4	3.3.3.5	3.3.3.6	3.3.3.7	3.3.3.8	3.3.3.9	3.3.4.1	3.3.4.2	3.3.4.3
3.3.4.4	3.3.4.5	3.3.4.6	3.3.4.7	3.3.4.8	3.3.4.9	3.3.5.1	3.3.5.2	3.3.5.3	3.3.5.4
3.3.5.5	3.3.5.6	3.3.5.7	3.3.5.8	3.3.5.9	3.3.6.1	3.3.6.2	3.3.6.3	3.3.6.4	3.3.6.5
3.3.6.6	3.3.6.7	3.3.6.8	3.3.6.9	3.3.7.1	3.3.7.2	3.3.7.3	3.3.7.4	3.3.7.5	3.3.7.6
3.3.7.7	3.3.7.8	3.3.7.9	3.3.8.1	3.3.8.2	3.3.8.3	3.3.8.4	3.3.8.5	3.3.8.6	3.3.8.7
3.3.8.8	3.3.8.9	3.3.9.1	3.3.9.2	3.3.9.3	3.3.9.4	3.3.9.5	3.3.9.6	3.3.9.7	3.3.9.8
3.3.9.9	3.4.1.1	3.4.1.2	3.4.1.3	3.4.1.4	3.4.1.5	3.4.1.6	3.4.1.7	3.4.1.8	3.4.1.9
3.4.2.1	3.4.2.2	3.4.2.3	3.4.2.4	3.4.2.5	3.4.2.6	3.4.2.7	3.4.2.8	3.4.2.9	3.4.3.1
3.4.3.2	3.4.3.3	3.4.3.4	3.4.3.5	3.4.3.6	3.4.3.7	3.4.3.8	3.4.3.9	3.4.4.1	3.4.4.2
3.4.4.3	3.4.4.4	3.4.4.5	3.4.4.6	3.4.4.7	3.4.4.8	3.4.4.9	3.4.5.1	3.4.5.2	3.4.5.3
3.4.5.4	3.4.5.5	3.4.5.6	3.4.5.7	3.4.5.8	3.4.5.9	3.4.6.1	3.4.6.2	3.4.6.3	3.4.6.4
3.4.6.5	3.4.6.6	3.4.6.7	3.4.6.8	3.4.6.9	3.4.7.1	3.4.7.2	3.4.7.3	3.4.7.4	3.4.7.5
3.4.7.6	3.4.7.7	3.4.7.8	3.4.7.9	3.4.8.1	3.4.8.2	3.4.8.3	3.4.8.4	3.4.8.5	3.4.8.6
3.4.8.7	3.4.8.8	3.4.8.9	3.4.9.1	3.4.9.2	3.4.9.3	3.4.9.4	3.4.9.5	3.4.9.6	3.4.9.7
3.4.9.8	3.4.9.9	3.5.1.1	3.5.1.2	3.5.1.3	3.5.1.4	3.5.1.5	3.5.1.6	3.5.1.7	3.5.1.8
3.5.1.9	3.5.2.1	3.5.2.2	3.5.2.3	3.5.2.4	3.5.2.5	3.5.2.6	3.5.2.7	3.5.2.8	3.5.2.9
3.5.3.1	3.5.3.2	3.5.3.3	3.5.3.4	3.5.3.5	3.5.3.6	3.5.3.7	3.5.3.8	3.5.3.9	3.5.4.1
3.5.4.2	3.5.4.3	3.5.4.4	3.5.4.5	3.5.4.6	3.5.4.7	3.5.4.8	3.5.4.9	3.5.5.1	3.5.5.2
3.5.5.3	3.5.5.4	3.5.5.5	3.5.5.6	3.5.5.7	3.5.5.8	3.5.5.9	3.5.6.1	3.5.6.2	3.5.6.3
3.5.6.4	3.5.6.5	3.5.6.6	3.5.6.7	3.5.6.8	3.5.6.9	3.5.7.1	3.5.7.2	3.5.7.3	3.5.7.4
3.5.7.5	3.5.7.6	3.5.7.7	3.5.7.8	3.5.7.9	3.5.8.1	3.5.8.2	3.5.8.3	3.5.8.4	3.5.8.5
3.5.8.6	3.5.8.7	3.5.8.8	3.5.8.9	3.5.9.1	3.5.9.2	3.5.9.3	3.5.9.4	3.5.9.5	3.5.9.6
3.5.9.7	3.5.9.8	3.5.9.9	3.6.1.1	3.6.1.2	3.6.1.3	3.6.1.4	3.6.1.5	3.6.1.6	3.6.1.7
3.6.1.8	3.6.1.9	3.6.2.1	3.6.2.2	3.6.2.3	3.6.2.4	3.6.2.5	3.6.2.6	3.6.2.7	3.6.2.8
3.6.2.9	3.6.3.1	3.6.3.2	3.6.3.3	3.6.3.4	3.6.3.5	3.6.3.6	3.6.3.7	3.6.3.8	3.6.3.9
3.6.4.1	3.6.4.2	3.6.4.3	3.6.4.4	3.6.4.5	3.6.4.6	3.6.4.7	3.6.4.8	3.6.4.9	3.6.5.1
3.6.5.2	3.6.5.3	3.6.5.4	3.6.5.5	3.6.5.6	3.6.5.7	3.6.5.8	3.6.5.9	3.6.6.1	3.6.6.2
3.6.6.3	3.6.6.4	3.6.6.5	3.6.6.6	3.6.6.7	3.6.6.8	3.6.6.9	3.6.7.1	3.6.7.2	3.6.7.3

Table 2 - continued

3.6.7.4	3.6.7.5	3.6.7.6	3.6.7.7	3.6.7.8	3.6.7.9	3.6.8.1	3.6.8.2	3.6.8.3	3.6.8.4
3.6.8.5	3.6.8.6	3.6.8.7	3.6.8.8	3.6.8.9	3.6.9.1	3.6.9.2	3.6.9.3	3.6.9.4	3.6.9.5
3.6.9.6	3.6.9.7	3.6.9.8	3.6.9.9	3.7.1.1	3.7.1.2	3.7.1.3	3.7.1.4	3.7.1.5	3.7.1.6
3.7.1.7	3.7.1.8	3.7.1.9	3.7.2.1	3.7.2.2	3.7.2.3	3.7.2.4	3.7.2.5	3.7.2.6	3.7.2.7
3.7.2.8	3.7.2.9	3.7.3.1	3.7.3.2	3.7.3.3	3.7.3.4	3.7.3.5	3.7.3.6	3.7.3.7	3.7.3.8
3.7.3.9	3.7.4.1	3.7.4.2	3.7.4.3	3.7.4.4	3.7.4.5	3.7.4.6	3.7.4.7	3.7.4.8	3.7.4.9
3.7.5.1	3.7.5.2	3.7.5.3	3.7.5.4	3.7.5.5	3.7.5.6	3.7.5.7	3.7.5.8	3.7.5.9	3.7.6.1
3.7.6.2	3.7.6.3	3.7.6.4	3.7.6.5	3.7.6.6	3.7.6.7	3.7.6.8	3.7.6.9	3.7.7.1	3.7.7.2
3.7.7.3	3.7.7.4	3.7.7.5	3.7.7.6	3.7.7.7	3.7.7.8	3.7.7.9	3.7.8.1	3.7.8.2	3.7.8.3
3.7.8.4	3.7.8.5	3.7.8.6	3.7.8.7	3.7.8.8	3.7.8.9	3.7.9.1	3.7.9.2	3.7.9.3	3.7.9.4
3.7.9.5	3.7.9.6	3.7.9.7	3.7.9.8	3.7.9.9	3.8.1.1	3.8.1.2	3.8.1.3	3.8.1.4	3.8.1.5
3.8.1.6	3.8.1.7	3.8.1.8	3.8.1.9	3.8.2.1	3.8.2.2	3.8.2.3	3.8.2.4	3.8.2.5	3.8.2.6
3.8.2.7	3.8.2.8	3.8.2.9	3.8.3.1	3.8.3.2	3.8.3.3	3.8.3.4	3.8.3.5	3.8.3.6	3.8.3.7
3.8.3.8	3.8.3.9	3.8.4.1	3.8.4.2	3.8.4.3	3.8.4.4	3.8.4.5	3.8.4.6	3.8.4.7	3.8.4.8
3.8.4.9	3.8.5.1	3.8.5.2	3.8.5.3	3.8.5.4	3.8.5.5	3.8.5.6	3.8.5.7	3.8.5.8	3.8.5.9
3.8.6.1	3.8.6.2	3.8.6.3	3.8.6.4	3.8.6.5	3.8.6.6	3.8.6.7	3.8.6.8	3.8.6.9	3.8.7.1
3.8.7.2	3.8.7.3	3.8.7.4	3.8.7.5	3.8.7.6	3.8.7.7	3.8.7.8	3.8.7.9	3.8.8.1	3.8.8.2
3.8.8.3	3.8.8.4	3.8.8.5	3.8.8.6	3.8.8.7	3.8.8.8	3.8.8.9	3.8.9.1	3.8.9.2	3.8.9.3
3.8.9.4	3.8.9.5	3.8.9.6	3.8.9.7	3.8.9.8	3.8.9.9	3.9.1.1	3.9.1.2	3.9.1.3	3.9.1.4
3.9.1.5	3.9.1.6	3.9.1.7	3.9.1.8	3.9.1.9	3.9.2.1	3.9.2.2	3.9.2.3	3.9.2.4	3.9.2.5
3.9.2.6	3.9.2.7	3.9.2.8	3.9.2.9	3.9.3.1	3.9.3.2	3.9.3.3	3.9.3.4	3.9.3.5	3.9.3.6
3.9.3.7	3.9.3.8	3.9.3.9	3.9.4.1	3.9.4.2	3.9.4.3	3.9.4.4	3.9.4.5	3.9.4.6	3.9.4.7
3.9.4.8	3.9.4.9	3.9.5.1	3.9.5.2	3.9.5.3	3.9.5.4	3.9.5.5	3.9.5.6	3.9.5.7	3.9.5.8
3.9.5.9	3.9.6.1	3.9.6.2	3.9.6.3	3.9.6.4	3.9.6.5	3.9.6.6	3.9.6.7	3.9.6.8	3.9.6.9
3.9.7.1	3.9.7.2	3.9.7.3	3.9.7.4	3.9.7.5	3.9.7.6	3.9.7.7	3.9.7.8	3.9.7.9	3.9.8.1
3.9.8.2	3.9.8.3	3.9.8.4	3.9.8.5	3.9.8.6	3.9.8.7	3.9.8.8	3.9.8.9	3.9.9.1	3.9.9.2
3.9.9.3	3.9.9.4	3.9.9.5	3.9.9.6	3.9.9.7	3.9.9.8	3.9.9.9	4.1.1.1	4.1.1.2	4.1.1.3
4.1.1.4	4.1.1.5	4.1.1.6	4.1.1.7	4.1.1.8	4.1.1.9	4.1.2.1	4.1.2.2	4.1.2.3	4.1.2.4
4.1.2.5	4.1.2.6	4.1.2.7	4.1.2.8	4.1.2.9	4.1.3.1	4.1.3.2	4.1.3.3	4.1.3.4	4.1.3.5
4.1.3.6	4.1.3.7	4.1.3.8	4.1.3.9	4.1.4.1	4.1.4.2	4.1.4.3	4.1.4.4	4.1.4.5	4.1.4.6
4.1.4.7	4.1.4.8	4.1.4.9	4.1.5.1	4.1.5.2	4.1.5.3	4.1.5.4	4.1.5.5	4.1.5.6	4.1.5.7
4.1.5.8	4.1.5.9	4.1.6.1	4.1.6.2	4.1.6.3	4.1.6.4	4.1.6.5	4.1.6.6	4.1.6.7	4.1.6.8
4.1.6.9	4.1.7.1	4.1.7.2	4.1.7.3	4.1.7.4	4.1.7.5	4.1.7.6	4.1.7.7	4.1.7.8	4.1.7.9
4.1.8.1	4.1.8.2	4.1.8.3	4.1.8.4	4.1.8.5	4.1.8.6	4.1.8.7	4.1.8.8	4.1.8.9	4.1.9.1
4.1.9.2	4.1.9.3	4.1.9.4	4.1.9.5	4.1.9.6	4.1.9.7	4.1.9.8	4.1.9.9	4.2.1.1	4.2.1.2
4.2.1.3	4.2.1.4	4.2.1.5	4.2.1.6	4.2.1.7	4.2.1.8	4.2.1.9	4.2.2.1	4.2.2.2	4.2.2.3
4.2.2.4	4.2.2.5	4.2.2.6	4.2.2.7	4.2.2.8	4.2.2.9	4.2.3.1	4.2.3.2	4.2.3.3	4.2.3.4
4.2.3.5	4.2.3.6	4.2.3.7	4.2.3.8	4.2.3.9	4.2.4.1	4.2.4.2	4.2.4.3	4.2.4.4	4.2.4.5
4.2.4.6	4.2.4.7	4.2.4.8	4.2.4.9	4.2.5.1	4.2.5.2	4.2.5.3	4.2.5.4	4.2.5.5	4.2.5.6
4.2.5.7	4.2.5.8	4.2.5.9	4.2.6.1	4.2.6.2	4.2.6.3	4.2.6.4	4.2.6.5	4.2.6.6	4.2.6.7
4.2.6.8	4.2.6.9	4.2.7.1	4.2.7.2	4.2.7.3	4.2.7.4	4.2.7.5	4.2.7.6	4.2.7.7	4.2.7.8
4.2.7.9	4.2.8.1	4.2.8.2	4.2.8.3	4.2.8.4	4.2.8.5	4.2.8.6	4.2.8.7	4.2.8.8	4.2.8.9
4.2.9.1	4.2.9.2	4.2.9.3	4.2.9.4	4.2.9.5	4.2.9.6	4.2.9.7	4.2.9.8	4.2.9.9	4.3.1.1
4.3.1.2	4.3.1.3	4.3.1.4	4.3.1.5	4.3.1.6	4.3.1.7	4.3.1.8	4.3.1.9	4.3.2.1	4.3.2.2
4.3.2.3	4.3.2.4	4.3.2.5	4.3.2.6	4.3.2.7	4.3.2.8	4.3.2.9	4.3.3.1	4.3.3.2	4.3.3.3
4.3.3.4	4.3.3.5	4.3.3.6	4.3.3.7	4.3.3.8	4.3.3.9	4.3.4.1	4.3.4.2	4.3.4.3	4.3.4.4
4.3.4.5	4.3.4.6	4.3.4.7	4.3.4.8	4.3.4.9	4.3.5.1	4.3.5.2	4.3.5.3	4.3.5.4	4.3.5.5
4.3.5.6	4.3.5.7	4.3.5.8	4.3.5.9	4.3.6.1	4.3.6.2	4.3.6.3	4.3.6.4	4.3.6.5	4.3.6.6

Table 2 - continued

4.3.6.7	4.3.6.8	4.3.6.9	4.3.7.1	4.3.7.2	4.3.7.3	4.3.7.4	4.3.7.5	4.3.7.6	4.3.7.7
4.3.7.8	4.3.7.9	4.3.8.1	4.3.8.2	4.3.8.3	4.3.8.4	4.3.8.5	4.3.8.6	4.3.8.7	4.3.8.8
4.3.8.9	4.3.9.1	4.3.9.2	4.3.9.3	4.3.9.4	4.3.9.5	4.3.9.6	4.3.9.7	4.3.9.8	4.3.9.9
4.4.1.1	4.4.1.2	4.4.1.3	4.4.1.4	4.4.1.5	4.4.1.6	4.4.1.7	4.4.1.8	4.4.1.9	4.4.2.1
4.4.2.2	4.4.2.3	4.4.2.4	4.4.2.5	4.4.2.6	4.4.2.7	4.4.2.8	4.4.2.9	4.4.3.1	4.4.3.2
4.4.3.3	4.4.3.4	4.4.3.5	4.4.3.6	4.4.3.7	4.4.3.8	4.4.3.9	4.4.4.1	4.4.4.2	4.4.4.3
4.4.4.4	4.4.4.5	4.4.4.6	4.4.4.7	4.4.4.8	4.4.4.9	4.4.5.1	4.4.5.2	4.4.5.3	4.4.5.4
4.4.5.5	4.4.5.6	4.4.5.7	4.4.5.8	4.4.5.9	4.4.6.1	4.4.6.2	4.4.6.3	4.4.6.4	4.4.6.5
4.4.6.6	4.4.6.7	4.4.6.8	4.4.6.9	4.4.7.1	4.4.7.2	4.4.7.3	4.4.7.4	4.4.7.5	4.4.7.6
4.4.7.7	4.4.7.8	4.4.7.9	4.4.8.1	4.4.8.2	4.4.8.3	4.4.8.4	4.4.8.5	4.4.8.6	4.4.8.7
4.4.8.8	4.4.8.9	4.4.9.1	4.4.9.2	4.4.9.3	4.4.9.4	4.4.9.5	4.4.9.6	4.4.9.7	4.4.9.8
4.4.9.9	4.5.1.1	4.5.1.2	4.5.1.3	4.5.1.4	4.5.1.5	4.5.1.6	4.5.1.7	4.5.1.8	4.5.1.9
4.5.2.1	4.5.2.2	4.5.2.3	4.5.2.4	4.5.2.5	4.5.2.6	4.5.2.7	4.5.2.8	4.5.2.9	4.5.3.1
4.5.3.2	4.5.3.3	4.5.3.4	4.5.3.5	4.5.3.6	4.5.3.7	4.5.3.8	4.5.3.9	4.5.4.1	4.5.4.2
4.5.4.3	4.5.4.4	4.5.4.5	4.5.4.6	4.5.4.7	4.5.4.8	4.5.4.9	4.5.5.1	4.5.5.2	4.5.5.3
4.5.5.4	4.5.5.5	4.5.5.6	4.5.5.7	4.5.5.8	4.5.5.9	4.5.6.1	4.5.6.2	4.5.6.3	4.5.6.4
4.5.6.5	4.5.6.6	4.5.6.7	4.5.6.8	4.5.6.9	4.5.7.1	4.5.7.2	4.5.7.3	4.5.7.4	4.5.7.5
4.5.7.6	4.5.7.7	4.5.7.8	4.5.7.9	4.5.8.1	4.5.8.2	4.5.8.3	4.5.8.4	4.5.8.5	4.5.8.6
4.5.8.7	4.5.8.8	4.5.8.9	4.5.9.1	4.5.9.2	4.5.9.3	4.5.9.4	4.5.9.5	4.5.9.6	4.5.9.7
4.5.9.8	4.5.9.9	4.6.1.1	4.6.1.2	4.6.1.3	4.6.1.4	4.6.1.5	4.6.1.6	4.6.1.7	4.6.1.8
4.6.1.9	4.6.2.1	4.6.2.2	4.6.2.3	4.6.2.4	4.6.2.5	4.6.2.6	4.6.2.7	4.6.2.8	4.6.2.9
4.6.3.1	4.6.3.2	4.6.3.3	4.6.3.4	4.6.3.5	4.6.3.6	4.6.3.7	4.6.3.8	4.6.3.9	4.6.4.1
4.6.4.2	4.6.4.3	4.6.4.4	4.6.4.5	4.6.4.6	4.6.4.7	4.6.4.8	4.6.4.9	4.6.5.1	4.6.5.2
4.6.5.3	4.6.5.4	4.6.5.5	4.6.5.6	4.6.5.7	4.6.5.8	4.6.5.9	4.6.6.1	4.6.6.2	4.6.6.3
4.6.6.4	4.6.6.5	4.6.6.6	4.6.6.7	4.6.6.8	4.6.6.9	4.6.7.1	4.6.7.2	4.6.7.3	4.6.7.4
4.6.7.5	4.6.7.6	4.6.7.7	4.6.7.8	4.6.7.9	4.6.8.1	4.6.8.2	4.6.8.3	4.6.8.4	4.6.8.5
4.6.8.6	4.6.8.7	4.6.8.8	4.6.8.9	4.6.9.1	4.6.9.2	4.6.9.3	4.6.9.4	4.6.9.5	4.6.9.6
4.6.9.7	4.6.9.8	4.6.9.9	4.7.1.1	4.7.1.2	4.7.1.3	4.7.1.4	4.7.1.5	4.7.1.6	4.7.1.7
4.7.1.8	4.7.1.9	4.7.2.1	4.7.2.2	4.7.2.3	4.7.2.4	4.7.2.5	4.7.2.6	4.7.2.7	4.7.2.8
4.7.2.9	4.7.3.1	4.7.3.2	4.7.3.3	4.7.3.4	4.7.3.5	4.7.3.6	4.7.3.7	4.7.3.8	4.7.3.9
4.7.4.1	4.7.4.2	4.7.4.3	4.7.4.4	4.7.4.5	4.7.4.6	4.7.4.7	4.7.4.8	4.7.4.9	4.7.5.1
4.7.5.2	4.7.5.3	4.7.5.4	4.7.5.5	4.7.5.6	4.7.5.7	4.7.5.8	4.7.5.9	4.7.6.1	4.7.6.2
4.7.6.3	4.7.6.4	4.7.6.5	4.7.6.6	4.7.6.7	4.7.6.8	4.7.6.9	4.7.7.1	4.7.7.2	4.7.7.3
4.7.7.4	4.7.7.5	4.7.7.6	4.7.7.7	4.7.7.8	4.7.7.9	4.7.8.1	4.7.8.2	4.7.8.3	4.7.8.4
4.7.8.5	4.7.8.6	4.7.8.7	4.7.8.8	4.7.8.9	4.7.9.1	4.7.9.2	4.7.9.3	4.7.9.4	4.7.9.5
4.7.9.6	4.7.9.7	4.7.9.8	4.7.9.9	4.8.1.1	4.8.1.2	4.8.1.3	4.8.1.4	4.8.1.5	4.8.1.6
4.8.1.7	4.8.1.8	4.8.1.9	4.8.2.1	4.8.2.2	4.8.2.3	4.8.2.4	4.8.2.5	4.8.2.6	4.8.2.7
4.8.2.8	4.8.2.9	4.8.3.1	4.8.3.2	4.8.3.3	4.8.3.4	4.8.3.5	4.8.3.6	4.8.3.7	4.8.3.8
4.8.3.9	4.8.4.1	4.8.4.2	4.8.4.3	4.8.4.4	4.8.4.5	4.8.4.6	4.8.4.7	4.8.4.8	4.8.4.9
4.8.5.1	4.8.5.2	4.8.5.3	4.8.5.4	4.8.5.5	4.8.5.6	4.8.5.7	4.8.5.8	4.8.5.9	4.8.6.1
4.8.6.2	4.8.6.3	4.8.6.4	4.8.6.5	4.8.6.6	4.8.6.7	4.8.6.8	4.8.6.9	4.8.7.1	4.8.7.2
4.8.7.3	4.8.7.4	4.8.7.5	4.8.7.6	4.8.7.7	4.8.7.8	4.8.7.9	4.8.8.1	4.8.8.2	4.8.8.3
4.8.8.4	4.8.8.5	4.8.8.6	4.8.8.7	4.8.8.8	4.8.8.9	4.8.9.1	4.8.9.2	4.8.9.3	4.8.9.4
4.8.9.5	4.8.9.6	4.8.9.7	4.8.9.8	4.8.9.9	4.9.1.1	4.9.1.2	4.9.1.3	4.9.1.4	4.9.1.5
4.9.1.6	4.9.1.7	4.9.1.8	4.9.1.9	4.9.2.1	4.9.2.2	4.9.2.3	4.9.2.4	4.9.2.5	4.9.2.6
4.9.2.7	4.9.2.8	4.9.2.9	4.9.3.1	4.9.3.2	4.9.3.3	4.9.3.4	4.9.3.5	4.9.3.6	4.9.3.7
4.9.3.8	4.9.3.9	4.9.4.1	4.9.4.2	4.9.4.3	4.9.4.4	4.9.4.5	4.9.4.6	4.9.4.7	4.9.4.8
4.9.4.9	4.9.5.1	4.9.5.2	4.9.5.3	4.9.5.4	4.9.5.5	4.9.5.6	4.9.5.7	4.9.5.8	4.9.5.9

Table 2 - continued

4.9.6.1	4.9.6.2	4.9.6.3	4.9.6.4	4.9.6.5	4.9.6.6	4.9.6.7	4.9.6.8	4.9.6.9	4.9.7.1
4.9.7.2	4.9.7.3	4.9.7.4	4.9.7.5	4.9.7.6	4.9.7.7	4.9.7.8	4.9.7.9	4.9.8.1	4.9.8.2
4.9.8.3	4.9.8.4	4.9.8.5	4.9.8.6	4.9.8.7	4.9.8.8	4.9.8.9	4.9.9.1	4.9.9.2	4.9.9.3
4.9.9.4	4.9.9.5	4.9.9.6	4.9.9.7	4.9.9.8	4.9.9.9	5.1.1.1	5.1.1.2	5.1.1.3	5.1.1.4
5.1.1.5	5.1.1.6	5.1.1.7	5.1.1.8	5.1.1.9	5.1.2.1	5.1.2.2	5.1.2.3	5.1.2.4	5.1.2.5
5.1.2.6	5.1.2.7	5.1.2.8	5.1.2.9	5.1.3.1	5.1.3.2	5.1.3.3	5.1.3.4	5.1.3.5	5.1.3.6
5.1.3.7	5.1.3.8	5.1.3.9	5.1.4.1	5.1.4.2	5.1.4.3	5.1.4.4	5.1.4.5	5.1.4.6	5.1.4.7
5.1.4.8	5.1.4.9	5.1.5.1	5.1.5.2	5.1.5.3	5.1.5.4	5.1.5.5	5.1.5.6	5.1.5.7	5.1.5.8
5.1.5.9	5.1.6.1	5.1.6.2	5.1.6.3	5.1.6.4	5.1.6.5	5.1.6.6	5.1.6.7	5.1.6.8	5.1.6.9
5.1.7.1	5.1.7.2	5.1.7.3	5.1.7.4	5.1.7.5	5.1.7.6	5.1.7.7	5.1.7.8	5.1.7.9	5.1.8.1
5.1.8.2	5.1.8.3	5.1.8.4	5.1.8.5	5.1.8.6	5.1.8.7	5.1.8.8	5.1.8.9	5.1.9.1	5.1.9.2
5.1.9.3	5.1.9.4	5.1.9.5	5.1.9.6	5.1.9.7	5.1.9.8	5.1.9.9	5.2.1.1	5.2.1.2	5.2.1.3
5.2.1.4	5.2.1.5	5.2.1.6	5.2.1.7	5.2.1.8	5.2.1.9	5.2.2.1	5.2.2.2	5.2.2.3	5.2.2.4
5.2.2.5	5.2.2.6	5.2.2.7	5.2.2.8	5.2.2.9	5.2.3.1	5.2.3.2	5.2.3.3	5.2.3.4	5.2.3.5
5.2.3.6	5.2.3.7	5.2.3.8	5.2.3.9	5.2.4.1	5.2.4.2	5.2.4.3	5.2.4.4	5.2.4.5	5.2.4.6
5.2.4.7	5.2.4.8	5.2.4.9	5.2.5.1	5.2.5.2	5.2.5.3	5.2.5.4	5.2.5.5	5.2.5.6	5.2.5.7
5.2.5.8	5.2.5.9	5.2.6.1	5.2.6.2	5.2.6.3	5.2.6.4	5.2.6.5	5.2.6.6	5.2.6.7	5.2.6.8
5.2.6.9	5.2.7.1	5.2.7.2	5.2.7.3	5.2.7.4	5.2.7.5	5.2.7.6	5.2.7.7	5.2.7.8	5.2.7.9
5.2.8.1	5.2.8.2	5.2.8.3	5.2.8.4	5.2.8.5	5.2.8.6	5.2.8.7	5.2.8.8	5.2.8.9	5.2.9.1
5.2.9.2	5.2.9.3	5.2.9.4	5.2.9.5	5.2.9.6	5.2.9.7	5.2.9.8	5.2.9.9	5.3.1.1	5.3.1.2
5.3.1.3	5.3.1.4	5.3.1.5	5.3.1.6	5.3.1.7	5.3.1.8	5.3.1.9	5.3.2.1	5.3.2.2	5.3.2.3
5.3.2.4	5.3.2.5	5.3.2.6	5.3.2.7	5.3.2.8	5.3.2.9	5.3.3.1	5.3.3.2	5.3.3.3	5.3.3.4
5.3.3.5	5.3.3.6	5.3.3.7	5.3.3.8	5.3.3.9	5.3.4.1	5.3.4.2	5.3.4.3	5.3.4.4	5.3.4.5
5.3.4.6	5.3.4.7	5.3.4.8	5.3.4.9	5.3.5.1	5.3.5.2	5.3.5.3	5.3.5.4	5.3.5.5	5.3.5.6
5.3.5.7	5.3.5.8	5.3.5.9	5.3.6.1	5.3.6.2	5.3.6.3	5.3.6.4	5.3.6.5	5.3.6.6	5.3.6.7
5.3.6.8	5.3.6.9	5.3.7.1	5.3.7.2	5.3.7.3	5.3.7.4	5.3.7.5	5.3.7.6	5.3.7.7	5.3.7.8
5.3.7.9	5.3.8.1	5.3.8.2	5.3.8.3	5.3.8.4	5.3.8.5	5.3.8.6	5.3.8.7	5.3.8.8	5.3.8.9
5.3.9.1	5.3.9.2	5.3.9.3	5.3.9.4	5.3.9.5	5.3.9.6	5.3.9.7	5.3.9.8	5.3.9.9	5.4.1.1
5.4.1.2	5.4.1.3	5.4.1.4	5.4.1.5	5.4.1.6	5.4.1.7	5.4.1.8	5.4.1.9	5.4.2.1	5.4.2.2
5.4.2.3	5.4.2.4	5.4.2.5	5.4.2.6	5.4.2.7	5.4.2.8	5.4.2.9	5.4.3.1	5.4.3.2	5.4.3.3
5.4.3.4	5.4.3.5	5.4.3.6	5.4.3.7	5.4.3.8	5.4.3.9	5.4.4.1	5.4.4.2	5.4.4.3	5.4.4.4
5.4.4.5	5.4.4.6	5.4.4.7	5.4.4.8	5.4.4.9	5.4.5.1	5.4.5.2	5.4.5.3	5.4.5.4	5.4.5.5
5.4.5.6	5.4.5.7	5.4.5.8	5.4.5.9	5.4.6.1	5.4.6.2	5.4.6.3	5.4.6.4	5.4.6.5	5.4.6.6
5.4.6.7	5.4.6.8	5.4.6.9	5.4.7.1	5.4.7.2	5.4.7.3	5.4.7.4	5.4.7.5	5.4.7.6	5.4.7.7
5.4.7.8	5.4.7.9	5.4.8.1	5.4.8.2	5.4.8.3	5.4.8.4	5.4.8.5	5.4.8.6	5.4.8.7	5.4.8.8
5.4.8.9	5.4.9.1	5.4.9.2	5.4.9.3	5.4.9.4	5.4.9.5	5.4.9.6	5.4.9.7	5.4.9.8	5.4.9.9
5.5.1.1	5.5.1.2	5.5.1.3	5.5.1.4	5.5.1.5	5.5.1.6	5.5.1.7	5.5.1.8	5.5.1.9	5.5.2.1
5.5.2.2	5.5.2.3	5.5.2.4	5.5.2.5	5.5.2.6	5.5.2.7	5.5.2.8	5.5.2.9	5.5.3.1	5.5.3.2
5.5.3.3	5.5.3.4	5.5.3.5	5.5.3.6	5.5.3.7	5.5.3.8	5.5.3.9	5.5.4.1	5.5.4.2	5.5.4.3
5.5.4.4	5.5.4.5	5.5.4.6	5.5.4.7	5.5.4.8	5.5.4.9	5.5.5.1	5.5.5.2	5.5.5.3	5.5.5.4
5.5.5.5	5.5.5.6	5.5.5.7	5.5.5.8	5.5.5.9	5.5.6.1	5.5.6.2	5.5.6.3	5.5.6.4	5.5.6.5
5.5.6.6	5.5.6.7	5.5.6.8	5.5.6.9	5.5.7.1	5.5.7.2	5.5.7.3	5.5.7.4	5.5.7.5	5.5.7.6
5.5.7.7	5.5.7.8	5.5.7.9	5.5.8.1	5.5.8.2	5.5.8.3	5.5.8.4	5.5.8.5	5.5.8.6	5.5.8.7
5.5.8.8	5.5.8.9	5.5.9.1	5.5.9.2	5.5.9.3	5.5.9.4	5.5.9.5	5.5.9.6	5.5.9.7	5.5.9.8
5.5.9.9	5.6.1.1	5.6.1.2	5.6.1.3	5.6.1.4	5.6.1.5	5.6.1.6	5.6.1.7	5.6.1.8	5.6.1.9
5.6.2.1	5.6.2.2	5.6.2.3	5.6.2.4	5.6.2.5	5.6.2.6	5.6.2.7	5.6.2.8	5.6.2.9	5.6.3.1
5.6.3.2	5.6.3.3	5.6.3.4	5.6.3.5	5.6.3.6	5.6.3.7	5.6.3.8	5.6.3.9	5.6.4.1	5.6.4.2
5.6.4.3	5.6.4.4	5.6.4.5	5.6.4.6	5.6.4.7	5.6.4.8	5.6.4.9	5.6.5.1	5.6.5.2	5.6.5.3

Table 2 - continued

5.6.5.4	5.6.5.5	5.6.5.6	5.6.5.7	5.6.5.8	5.6.5.9	5.6.6.1	5.6.6.2	5.6.6.3	5.6.6.4
5.6.6.5	5.6.6.6	5.6.6.7	5.6.6.8	5.6.6.9	5.6.7.1	5.6.7.2	5.6.7.3	5.6.7.4	5.6.7.5
5.6.7.6	5.6.7.7	5.6.7.8	5.6.7.9	5.6.8.1	5.6.8.2	5.6.8.3	5.6.8.4	5.6.8.5	5.6.8.6
5.6.8.7	5.6.8.8	5.6.8.9	5.6.9.1	5.6.9.2	5.6.9.3	5.6.9.4	5.6.9.5	5.6.9.6	5.6.9.7
5.6.9.8	5.6.9.9	5.7.1.1	5.7.1.2	5.7.1.3	5.7.1.4	5.7.1.5	5.7.1.6	5.7.1.7	5.7.1.8
5.7.1.9	5.7.2.1	5.7.2.2	5.7.2.3	5.7.2.4	5.7.2.5	5.7.2.6	5.7.2.7	5.7.2.8	5.7.2.9
5.7.3.1	5.7.3.2	5.7.3.3	5.7.3.4	5.7.3.5	5.7.3.6	5.7.3.7	5.7.3.8	5.7.3.9	5.7.4.1
5.7.4.2	5.7.4.3	5.7.4.4	5.7.4.5	5.7.4.6	5.7.4.7	5.7.4.8	5.7.4.9	5.7.5.1	5.7.5.2
5.7.5.3	5.7.5.4	5.7.5.5	5.7.5.6	5.7.5.7	5.7.5.8	5.7.5.9	5.7.6.1	5.7.6.2	5.7.6.3
5.7.6.4	5.7.6.5	5.7.6.6	5.7.6.7	5.7.6.8	5.7.6.9	5.7.7.1	5.7.7.2	5.7.7.3	5.7.7.4
5.7.7.5	5.7.7.6	5.7.7.7	5.7.7.8	5.7.7.9	5.7.8.1	5.7.8.2	5.7.8.3	5.7.8.4	5.7.8.5
5.7.8.6	5.7.8.7	5.7.8.8	5.7.8.9	5.7.9.1	5.7.9.2	5.7.9.3	5.7.9.4	5.7.9.5	5.7.9.6
5.7.9.7	5.7.9.8	5.7.9.9	5.8.1.1	5.8.1.2	5.8.1.3	5.8.1.4	5.8.1.5	5.8.1.6	5.8.1.7
5.8.1.8	5.8.1.9	5.8.2.1	5.8.2.2	5.8.2.3	5.8.2.4	5.8.2.5	5.8.2.6	5.8.2.7	5.8.2.8
5.8.2.9	5.8.3.1	5.8.3.2	5.8.3.3	5.8.3.4	5.8.3.5	5.8.3.6	5.8.3.7	5.8.3.8	5.8.3.9
5.8.4.1	5.8.4.2	5.8.4.3	5.8.4.4	5.8.4.5	5.8.4.6	5.8.4.7	5.8.4.8	5.8.4.9	5.8.5.1
5.8.5.2	5.8.5.3	5.8.5.4	5.8.5.5	5.8.5.6	5.8.5.7	5.8.5.8	5.8.5.9	5.8.6.1	5.8.6.2
5.8.6.3	5.8.6.4	5.8.6.5	5.8.6.6	5.8.6.7	5.8.6.8	5.8.6.9	5.8.7.1	5.8.7.2	5.8.7.3
5.8.7.4	5.8.7.5	5.8.7.6	5.8.7.7	5.8.7.8	5.8.7.9	5.8.8.1	5.8.8.2	5.8.8.3	5.8.8.4
5.8.8.5	5.8.8.6	5.8.8.7	5.8.8.8	5.8.8.9	5.8.9.1	5.8.9.2	5.8.9.3	5.8.9.4	5.8.9.5
5.8.9.6	5.8.9.7	5.8.9.8	5.8.9.9	5.9.1.1	5.9.1.2	5.9.1.3	5.9.1.4	5.9.1.5	5.9.1.6
5.9.1.7	5.9.1.8	5.9.1.9	5.9.2.1	5.9.2.2	5.9.2.3	5.9.2.4	5.9.2.5	5.9.2.6	5.9.2.7
5.9.2.8	5.9.2.9	5.9.3.1	5.9.3.2	5.9.3.3	5.9.3.4	5.9.3.5	5.9.3.6	5.9.3.7	5.9.3.8
5.9.3.9	5.9.4.1	5.9.4.2	5.9.4.3	5.9.4.4	5.9.4.5	5.9.4.6	5.9.4.7	5.9.4.8	5.9.4.9
5.9.5.1	5.9.5.2	5.9.5.3	5.9.5.4	5.9.5.5	5.9.5.6	5.9.5.7	5.9.5.8	5.9.5.9	5.9.6.1
5.9.6.2	5.9.6.3	5.9.6.4	5.9.6.5	5.9.6.6	5.9.6.7	5.9.6.8	5.9.6.9	5.9.7.1	5.9.7.2
5.9.7.3	5.9.7.4	5.9.7.5	5.9.7.6	5.9.7.7	5.9.7.8	5.9.7.9	5.9.8.1	5.9.8.2	5.9.8.3
5.9.8.4	5.9.8.5	5.9.8.6	5.9.8.7	5.9.8.8	5.9.8.9	5.9.9.1	5.9.9.2	5.9.9.3	5.9.9.4
5.9.9.5	5.9.9.6	5.9.9.7	5.9.9.8	5.9.9.9	6.1.1.1	6.1.1.2	6.1.1.3	6.1.1.4	6.1.1.5
6.1.1.6	6.1.1.7	6.1.1.8	6.1.1.9	6.1.2.1	6.1.2.2	6.1.2.3	6.1.2.4	6.1.2.5	6.1.2.6
6.1.2.7	6.1.2.8	6.1.2.9	6.1.3.1	6.1.3.2	6.1.3.3	6.1.3.4	6.1.3.5	6.1.3.6	6.1.3.7
6.1.3.8	6.1.3.9	6.1.4.1	6.1.4.2	6.1.4.3	6.1.4.4	6.1.4.5	6.1.4.6	6.1.4.7	6.1.4.8
6.1.4.9	6.1.5.1	6.1.5.2	6.1.5.3	6.1.5.4	6.1.5.5	6.1.5.6	6.1.5.7	6.1.5.8	6.1.5.9
6.1.6.1	6.1.6.2	6.1.6.3	6.1.6.4	6.1.6.5	6.1.6.6	6.1.6.7	6.1.6.8	6.1.6.9	6.1.7.1
6.1.7.2	6.1.7.3	6.1.7.4	6.1.7.5	6.1.7.6	6.1.7.7	6.1.7.8	6.1.7.9	6.1.8.1	6.1.8.2
6.1.8.3	6.1.8.4	6.1.8.5	6.1.8.6	6.1.8.7	6.1.8.8	6.1.8.9	6.1.9.1	6.1.9.2	6.1.9.3
6.1.9.4	6.1.9.5	6.1.9.6	6.1.9.7	6.1.9.8	6.1.9.9	6.2.1.1	6.2.1.2	6.2.1.3	6.2.1.4
6.2.1.5	6.2.1.6	6.2.1.7	6.2.1.8	6.2.1.9	6.2.2.1	6.2.2.2	6.2.2.3	6.2.2.4	6.2.2.5
6.2.2.6	6.2.2.7	6.2.2.8	6.2.2.9	6.2.3.1	6.2.3.2	6.2.3.3	6.2.3.4	6.2.3.5	6.2.3.6
6.2.3.7	6.2.3.8	6.2.3.9	6.2.4.1	6.2.4.2	6.2.4.3	6.2.4.4	6.2.4.5	6.2.4.6	6.2.4.7
6.2.4.8	6.2.4.9	6.2.5.1	6.2.5.2	6.2.5.3	6.2.5.4	6.2.5.5	6.2.5.6	6.2.5.7	6.2.5.8
6.2.5.9	6.2.6.1	6.2.6.2	6.2.6.3	6.2.6.4	6.2.6.5	6.2.6.6	6.2.6.7	6.2.6.8	6.2.6.9
6.2.7.1	6.2.7.2	6.2.7.3	6.2.7.4	6.2.7.5	6.2.7.6	6.2.7.7	6.2.7.8	6.2.7.9	6.2.8.1
6.2.8.2	6.2.8.3	6.2.8.4	6.2.8.5	6.2.8.6	6.2.8.7	6.2.8.8	6.2.8.9	6.2.9.1	6.2.9.2
6.2.9.3	6.2.9.4	6.2.9.5	6.2.9.6	6.2.9.7	6.2.9.8	6.2.9.9	6.3.1.1	6.3.1.2	6.3.1.3
6.3.1.4	6.3.1.5	6.3.1.6	6.3.1.7	6.3.1.8	6.3.1.9	6.3.2.1	6.3.2.2	6.3.2.3	6.3.2.4
6.3.2.5	6.3.2.6	6.3.2.7	6.3.2.8	6.3.2.9	6.3.3.1	6.3.3.2	6.3.3.3	6.3.3.4	6.3.3.5
6.3.3.6	6.3.3.7	6.3.3.8	6.3.3.9	6.3.4.1	6.3.4.2	6.3.4.3	6.3.4.4	6.3.4.5	6.3.4.6

Table 2- continued

6.3.4.7	6.3.4.8	6.3.4.9	6.3.5.1	6.3.5.2	6.3.5.3	6.3.5.4	6.3.5.5	6.3.5.6	6.3.5.7
6.3.5.8	6.3.5.9	6.3.6.1	6.3.6.2	6.3.6.3	6.3.6.4	6.3.6.5	6.3.6.6	6.3.6.7	6.3.6.8
6.3.6.9	6.3.7.1	6.3.7.2	6.3.7.3	6.3.7.4	6.3.7.5	6.3.7.6	6.3.7.7	6.3.7.8	6.3.7.9
6.3.8.1	6.3.8.2	6.3.8.3	6.3.8.4	6.3.8.5	6.3.8.6	6.3.8.7	6.3.8.8	6.3.8.9	6.3.9.1
6.3.9.2	6.3.9.3	6.3.9.4	6.3.9.5	6.3.9.6	6.3.9.7	6.3.9.8	6.3.9.9	6.4.1.1	6.4.1.2
6.4.1.3	6.4.1.4	6.4.1.5	6.4.1.6	6.4.1.7	6.4.1.8	6.4.1.9	6.4.2.1	6.4.2.2	6.4.2.3
6.4.2.4	6.4.2.5	6.4.2.6	6.4.2.7	6.4.2.8	6.4.2.9	6.4.3.1	6.4.3.2	6.4.3.3	6.4.3.4
6.4.3.5	6.4.3.6	6.4.3.7	6.4.3.8	6.4.3.9	6.4.4.1	6.4.4.2	6.4.4.3	6.4.4.4	6.4.4.5
6.4.4.6	6.4.4.7	6.4.4.8	6.4.4.9	6.4.5.1	6.4.5.2	6.4.5.3	6.4.5.4	6.4.5.5	6.4.5.6
6.4.5.7	6.4.5.8	6.4.5.9	6.4.6.1	6.4.6.2	6.4.6.3	6.4.6.4	6.4.6.5	6.4.6.6	6.4.6.7
6.4.6.8	6.4.6.9	6.4.7.1	6.4.7.2	6.4.7.3	6.4.7.4	6.4.7.5	6.4.7.6	6.4.7.7	6.4.7.8
6.4.7.9	6.4.8.1	6.4.8.2	6.4.8.3	6.4.8.4	6.4.8.5	6.4.8.6	6.4.8.7	6.4.8.8	6.4.8.9
6.4.9.1	6.4.9.2	6.4.9.3	6.4.9.4	6.4.9.5	6.4.9.6	6.4.9.7	6.4.9.8	6.4.9.9	6.5.1.1
6.5.1.2	6.5.1.3	6.5.1.4	6.5.1.5	6.5.1.6	6.5.1.7	6.5.1.8	6.5.1.9	6.5.2.1	6.5.2.2
6.5.2.3	6.5.2.4	6.5.2.5	6.5.2.6	6.5.2.7	6.5.2.8	6.5.2.9	6.5.3.1	6.5.3.2	6.5.3.3
6.5.3.4	6.5.3.5	6.5.3.6	6.5.3.7	6.5.3.8	6.5.3.9	6.5.4.1	6.5.4.2	6.5.4.3	6.5.4.4
6.5.4.5	6.5.4.6	6.5.4.7	6.5.4.8	6.5.4.9	6.5.5.1	6.5.5.2	6.5.5.3	6.5.5.4	6.5.5.5
6.5.5.6	6.5.5.7	6.5.5.8	6.5.5.9	6.5.6.1	6.5.6.2	6.5.6.3	6.5.6.4	6.5.6.5	6.5.6.6
6.5.6.7	6.5.6.8	6.5.6.9	6.5.7.1	6.5.7.2	6.5.7.3	6.5.7.4	6.5.7.5	6.5.7.6	6.5.7.7
6.5.7.8	6.5.7.9	6.5.8.1	6.5.8.2	6.5.8.3	6.5.8.4	6.5.8.5	6.5.8.6	6.5.8.7	6.5.8.8
6.5.8.9	6.5.9.1	6.5.9.2	6.5.9.3	6.5.9.4	6.5.9.5	6.5.9.6	6.5.9.7	6.5.9.8	6.5.9.9
6.6.1.1	6.6.1.2	6.6.1.3	6.6.1.4	6.6.1.5	6.6.1.6	6.6.1.7	6.6.1.8	6.6.1.9	6.6.2.1
6.6.2.2	6.6.2.3	6.6.2.4	6.6.2.5	6.6.2.6	6.6.2.7	6.6.2.8	6.6.2.9	6.6.3.1	6.6.3.2
6.6.3.3	6.6.3.4	6.6.3.5	6.6.3.6	6.6.3.7	6.6.3.8	6.6.3.9	6.6.4.1	6.6.4.2	6.6.4.3
6.6.4.4	6.6.4.5	6.6.4.6	6.6.4.7	6.6.4.8	6.6.4.9	6.6.5.1	6.6.5.2	6.6.5.3	6.6.5.4
6.6.5.5	6.6.5.6	6.6.5.7	6.6.5.8	6.6.5.9	6.6.6.1	6.6.6.2	6.6.6.3	6.6.6.4	6.6.6.5
6.6.6.6	6.6.6.7	6.6.6.8	6.6.6.9	6.6.7.1	6.6.7.2	6.6.7.3	6.6.7.4	6.6.7.5	6.6.7.6
6.6.7.7	6.6.7.8	6.6.7.9	6.6.8.1	6.6.8.2	6.6.8.3	6.6.8.4	6.6.8.5	6.6.8.6	6.6.8.7
6.6.8.8	6.6.8.9	6.6.9.1	6.6.9.2	6.6.9.3	6.6.9.4	6.6.9.5	6.6.9.6	6.6.9.7	6.6.9.8
6.6.9.9	6.7.1.1	6.7.1.2	6.7.1.3	6.7.1.4	6.7.1.5	6.7.1.6	6.7.1.7	6.7.1.8	6.7.1.9
6.7.2.1	6.7.2.2	6.7.2.3	6.7.2.4	6.7.2.5	6.7.2.6	6.7.2.7	6.7.2.8	6.7.2.9	6.7.3.1
6.7.3.2	6.7.3.3	6.7.3.4	6.7.3.5	6.7.3.6	6.7.3.7	6.7.3.8	6.7.3.9	6.7.4.1	6.7.4.2
6.7.4.3	6.7.4.4	6.7.4.5	6.7.4.6	6.7.4.7	6.7.4.8	6.7.4.9	6.7.5.1	6.7.5.2	6.7.5.3
6.7.5.4	6.7.5.5	6.7.5.6	6.7.5.7	6.7.5.8	6.7.5.9	6.7.6.1	6.7.6.2	6.7.6.3	6.7.6.4
6.7.6.5	6.7.6.6	6.7.6.7	6.7.6.8	6.7.6.9	6.7.7.1	6.7.7.2	6.7.7.3	6.7.7.4	6.7.7.5
6.7.7.6	6.7.7.7	6.7.7.8	6.7.7.9	6.7.8.1	6.7.8.2	6.7.8.3	6.7.8.4	6.7.8.5	6.7.8.6
6.7.8.7	6.7.8.8	6.7.8.9	6.7.9.1	6.7.9.2	6.7.9.3	6.7.9.4	6.7.9.5	6.7.9.6	6.7.9.7
6.7.9.8	6.7.9.9	6.8.1.1	6.8.1.2	6.8.1.3	6.8.1.4	6.8.1.5	6.8.1.6	6.8.1.7	6.8.1.8
6.8.1.9	6.8.2.1	6.8.2.2	6.8.2.3	6.8.2.4	6.8.2.5	6.8.2.6	6.8.2.7	6.8.2.8	6.8.2.9
6.8.3.1	6.8.3.2	6.8.3.3	6.8.3.4	6.8.3.5	6.8.3.6	6.8.3.7	6.8.3.8	6.8.3.9	6.8.4.1
6.8.4.2	6.8.4.3	6.8.4.4	6.8.4.5	6.8.4.6	6.8.4.7	6.8.4.8	6.8.4.9	6.8.5.1	6.8.5.2
6.8.5.3	6.8.5.4	6.8.5.5	6.8.5.6	6.8.5.7	6.8.5.8	6.8.5.9	6.8.6.1	6.8.6.2	6.8.6.3
6.8.6.4	6.8.6.5	6.8.6.6	6.8.6.7	6.8.6.8	6.8.6.9	6.8.7.1	6.8.7.2	6.8.7.3	6.8.7.4
6.8.7.5	6.8.7.6	6.8.7.7	6.8.7.8	6.8.7.9	6.8.8.1	6.8.8.2	6.8.8.3	6.8.8.4	6.8.8.5
6.8.8.6	6.8.8.7	6.8.8.8	6.8.8.9	6.8.9.1	6.8.9.2	6.8.9.3	6.8.9.4	6.8.9.5	6.8.9.6
6.8.9.7	6.8.9.8	6.8.9.9	6.9.1.1	6.9.1.2	6.9.1.3	6.9.1.4	6.9.1.5	6.9.1.6	6.9.1.7
6.9.1.8	6.9.1.9	6.9.2.1	6.9.2.2	6.9.2.3	6.9.2.4	6.9.2.5	6.9.2.6	6.9.2.7	6.9.2.8
6.9.2.9	6.9.3.1	6.9.3.2	6.9.3.3	6.9.3.4	6.9.3.5	6.9.3.6	6.9.3.7	6.9.3.8	6.9.3.9

Table 2 - continued

6.9.4.1	6.9.4.2	6.9.4.3	6.9.4.4	6.9.4.5	6.9.4.6	6.9.4.7	6.9.4.8	6.9.4.9	6.9.5.1
6.9.5.2	6.9.5.3	6.9.5.4	6.9.5.5	6.9.5.6	6.9.5.7	6.9.5.8	6.9.5.9	6.9.6.1	6.9.6.2
6.9.6.3	6.9.6.4	6.9.6.5	6.9.6.6	6.9.6.7	6.9.6.8	6.9.6.9	6.9.7.1	6.9.7.2	6.9.7.3
6.9.7.4	6.9.7.5	6.9.7.6	6.9.7.7	6.9.7.8	6.9.7.9	6.9.8.1	6.9.8.2	6.9.8.3	6.9.8.4
6.9.8.5	6.9.8.6	6.9.8.7	6.9.8.8	6.9.8.9	6.9.9.1	6.9.9.2	6.9.9.3	6.9.9.4	6.9.9.5
6.9.9.6	6.9.9.7	6.9.9.8	6.9.9.9	7.1.1.1	7.1.1.2	7.1.1.3	7.1.1.4	7.1.1.5	7.1.1.6
7.1.1.7	7.1.1.8	7.1.1.9	7.1.2.1	7.1.2.2	7.1.2.3	7.1.2.4	7.1.2.5	7.1.2.6	7.1.2.7
7.1.2.8	7.1.2.9	7.1.3.1	7.1.3.2	7.1.3.3	7.1.3.4	7.1.3.5	7.1.3.6	7.1.3.7	7.1.3.8
7.1.3.9	7.1.4.1	7.1.4.2	7.1.4.3	7.1.4.4	7.1.4.5	7.1.4.6	7.1.4.7	7.1.4.8	7.1.4.9
7.1.5.1	7.1.5.2	7.1.5.3	7.1.5.4	7.1.5.5	7.1.5.6	7.1.5.7	7.1.5.8	7.1.5.9	7.1.6.1
7.1.6.2	7.1.6.3	7.1.6.4	7.1.6.5	7.1.6.6	7.1.6.7	7.1.6.8	7.1.6.9	7.1.7.1	7.1.7.2
7.1.7.3	7.1.7.4	7.1.7.5	7.1.7.6	7.1.7.7	7.1.7.8	7.1.7.9	7.1.8.1	7.1.8.2	7.1.8.3
7.1.8.4	7.1.8.5	7.1.8.6	7.1.8.7	7.1.8.8	7.1.8.9	7.1.9.1	7.1.9.2	7.1.9.3	7.1.9.4
7.1.9.5	7.1.9.6	7.1.9.7	7.1.9.8	7.1.9.9	7.2.1.1	7.2.1.2	7.2.1.3	7.2.1.4	7.2.1.5
7.2.1.6	7.2.1.7	7.2.1.8	7.2.1.9	7.2.2.1	7.2.2.2	7.2.2.3	7.2.2.4	7.2.2.5	7.2.2.6
7.2.2.7	7.2.2.8	7.2.2.9	7.2.3.1	7.2.3.2	7.2.3.3	7.2.3.4	7.2.3.5	7.2.3.6	7.2.3.7
7.2.3.8	7.2.3.9	7.2.4.1	7.2.4.2	7.2.4.3	7.2.4.4	7.2.4.5	7.2.4.6	7.2.4.7	7.2.4.8
7.2.4.9	7.2.5.1	7.2.5.2	7.2.5.3	7.2.5.4	7.2.5.5	7.2.5.6	7.2.5.7	7.2.5.8	7.2.5.9
7.2.6.1	7.2.6.2	7.2.6.3	7.2.6.4	7.2.6.5	7.2.6.6	7.2.6.7	7.2.6.8	7.2.6.9	7.2.7.1
7.2.7.2	7.2.7.3	7.2.7.4	7.2.7.5	7.2.7.6	7.2.7.7	7.2.7.8	7.2.7.9	7.2.8.1	7.2.8.2
7.2.8.3	7.2.8.4	7.2.8.5	7.2.8.6	7.2.8.7	7.2.8.8	7.2.8.9	7.2.9.1	7.2.9.2	7.2.9.3
7.2.9.4	7.2.9.5	7.2.9.6	7.2.9.7	7.2.9.8	7.2.9.9	7.3.1.1	7.3.1.2	7.3.1.3	7.3.1.4
7.3.1.5	7.3.1.6	7.3.1.7	7.3.1.8	7.3.1.9	7.3.2.1	7.3.2.2	7.3.2.3	7.3.2.4	7.3.2.5
7.3.2.6	7.3.2.7	7.3.2.8	7.3.2.9	7.3.3.1	7.3.3.2	7.3.3.3	7.3.3.4	7.3.3.5	7.3.3.6
7.3.3.7	7.3.3.8	7.3.3.9	7.3.4.1	7.3.4.2	7.3.4.3	7.3.4.4	7.3.4.5	7.3.4.6	7.3.4.7
7.3.4.8	7.3.4.9	7.3.5.1	7.3.5.2	7.3.5.3	7.3.5.4	7.3.5.5	7.3.5.6	7.3.5.7	7.3.5.8
7.3.5.9	7.3.6.1	7.3.6.2	7.3.6.3	7.3.6.4	7.3.6.5	7.3.6.6	7.3.6.7	7.3.6.8	7.3.6.9
7.3.7.1	7.3.7.2	7.3.7.3	7.3.7.4	7.3.7.5	7.3.7.6	7.3.7.7	7.3.7.8	7.3.7.9	7.3.8.1
7.3.8.2	7.3.8.3	7.3.8.4	7.3.8.5	7.3.8.6	7.3.8.7	7.3.8.8	7.3.8.9	7.3.9.1	7.3.9.2
7.3.9.3	7.3.9.4	7.3.9.5	7.3.9.6	7.3.9.7	7.3.9.8	7.3.9.9	7.4.1.1	7.4.1.2	7.4.1.3
7.4.1.4	7.4.1.5	7.4.1.6	7.4.1.7	7.4.1.8	7.4.1.9	7.4.2.1	7.4.2.2	7.4.2.3	7.4.2.4
7.4.2.5	7.4.2.6	7.4.2.7	7.4.2.8	7.4.2.9	7.4.3.1	7.4.3.2	7.4.3.3	7.4.3.4	7.4.3.5
7.4.3.6	7.4.3.7	7.4.3.8	7.4.3.9	7.4.4.1	7.4.4.2	7.4.4.3	7.4.4.4	7.4.4.5	7.4.4.6
7.4.4.7	7.4.4.8	7.4.4.9	7.4.5.1	7.4.5.2	7.4.5.3	7.4.5.4	7.4.5.5	7.4.5.6	7.4.5.7
7.4.5.8	7.4.5.9	7.4.6.1	7.4.6.2	7.4.6.3	7.4.6.4	7.4.6.5	7.4.6.6	7.4.6.7	7.4.6.8
7.4.6.9	7.4.7.1	7.4.7.2	7.4.7.3	7.4.7.4	7.4.7.5	7.4.7.6	7.4.7.7	7.4.7.8	7.4.7.9
7.4.8.1	7.4.8.2	7.4.8.3	7.4.8.4	7.4.8.5	7.4.8.6	7.4.8.7	7.4.8.8	7.4.8.9	7.4.9.1
7.4.9.2	7.4.9.3	7.4.9.4	7.4.9.5	7.4.9.6	7.4.9.7	7.4.9.8	7.4.9.9	7.5.1.1	7.5.1.2
7.5.1.3	7.5.1.4	7.5.1.5	7.5.1.6	7.5.1.7	7.5.1.8	7.5.1.9	7.5.2.1	7.5.2.2	7.5.2.3
7.5.2.4	7.5.2.5	7.5.2.6	7.5.2.7	7.5.2.8	7.5.2.9	7.5.3.1	7.5.3.2	7.5.3.3	7.5.3.4
7.5.3.5	7.5.3.6	7.5.3.7	7.5.3.8	7.5.3.9	7.5.4.1	7.5.4.2	7.5.4.3	7.5.4.4	7.5.4.5
7.5.4.6	7.5.4.7	7.5.4.8	7.5.4.9	7.5.5.1	7.5.5.2	7.5.5.3	7.5.5.4	7.5.5.5	7.5.5.6
7.5.5.7	7.5.5.8	7.5.5.9	7.5.6.1	7.5.6.2	7.5.6.3	7.5.6.4	7.5.6.5	7.5.6.6	7.5.6.7
7.5.6.8	7.5.6.9	7.5.7.1	7.5.7.2	7.5.7.3	7.5.7.4	7.5.7.5	7.5.7.6	7.5.7.7	7.5.7.8
7.5.7.9	7.5.8.1	7.5.8.2	7.5.8.3	7.5.8.4	7.5.8.5	7.5.8.6	7.5.8.7	7.5.8.8	7.5.8.9
7.5.9.1	7.5.9.2	7.5.9.3	7.5.9.4	7.5.9.5	7.5.9.6	7.5.9.7	7.5.9.8	7.5.9.9	7.6.1.1
7.6.1.2	7.6.1.3	7.6.1.4	7.6.1.5	7.6.1.6	7.6.1.7	7.6.1.8	7.6.1.9	7.6.2.1	7.6.2.2
7.6.2.3	7.6.2.4	7.6.2.5	7.6.2.6	7.6.2.7	7.6.2.8	7.6.2.9	7.6.3.1	7.6.3.2	7.6.3.3

Table 2 - continued

7.6.3.4	7.6.3.5	7.6.3.6	7.6.3.7	7.6.3.8	7.6.3.9	7.6.4.1	7.6.4.2	7.6.4.3	7.6.4.4
7.6.4.5	7.6.4.6	7.6.4.7	7.6.4.8	7.6.4.9	7.6.5.1	7.6.5.2	7.6.5.3	7.6.5.4	7.6.5.5
7.6.5.6	7.6.5.7	7.6.5.8	7.6.5.9	7.6.6.1	7.6.6.2	7.6.6.3	7.6.6.4	7.6.6.5	7.6.6.6
7.6.6.7	7.6.6.8	7.6.6.9	7.6.7.1	7.6.7.2	7.6.7.3	7.6.7.4	7.6.7.5	7.6.7.6	7.6.7.7
7.6.7.8	7.6.7.9	7.6.8.1	7.6.8.2	7.6.8.3	7.6.8.4	7.6.8.5	7.6.8.6	7.6.8.7	7.6.8.8
7.6.8.9	7.6.9.1	7.6.9.2	7.6.9.3	7.6.9.4	7.6.9.5	7.6.9.6	7.6.9.7	7.6.9.8	7.6.9.9
7.7.1.1	7.7.1.2	7.7.1.3	7.7.1.4	7.7.1.5	7.7.1.6	7.7.1.7	7.7.1.8	7.7.1.9	7.7.2.1
7.7.2.2	7.7.2.3	7.7.2.4	7.7.2.5	7.7.2.6	7.7.2.7	7.7.2.B	7.7.2.9	7.7.3.1	7.7.3.2
7.7.3.3	7.7.3.4	7.7.3.5	7.7.3.6	7.7.3.7	7.7.3.8	7.7.3.9	7.7.4.1	7.7.4.2	7.7.4.3
7.7.4.4	7.7.4.5	7.7.4.6	7.7.4.7	7.7.4.8	7.7.4.9	7.7.5.1	7.7.5.2	7.7.5.3	7.7.5.4
7.7.5.5	7.7.5.6	7.7.5.7	7.7.5.8	7.7.5.9	7.7.6.1	7.7.6.2	7.7.6.3	7.7.6.4	7.7.6.5
7.7.6.6	7.7.6.7	7.7.6.8	7.7.6.9	7.7.7.1	7.7.7.2	7.7.7.3	7.7.7.4	7.7.7.5	7.7.7.6
7.7.7.7	7.7.7.8	7.7.7.9	7.7.8.1	7.7.8.2	7.7.8.3	7.7.8.4	7.7.8.5	7.7.8.6	7.7.8.7
7.7.8.8	7.7.8.9	7.7.9.1	7.7.9.2	7.7.9.3	7.7.9.4	7.7.9.5	7.7.9.6	7.7.9.7	7.7.9.8
7.7.9.9	7.8.1.1	7.8.1.2	7.8.1.3	7.8.1.4	7.8.1.5	7.8.1.6	7.8.1.7	7.8.1.8	7.8.1.9
7.8.2.1	7.8.2.2	7.8.2.3	7.8.2.4	7.8.2.5	7.8.2.6	7.8.2.7	7.8.2.8	7.8.2.9	7.8.3.1
7.8.3.2	7.8.3.3	7.8.3.4	7.8.3.5	7.8.3.6	7.8.3.7	7.8.3.8	7.8.3.9	7.8.4.1	7.8.4.2
7.8.4.3	7.8.4.4	7.8.4.5	7.8.4.6	7.8.4.7	7.8.4.8	7.8.4.9	7.8.5.1	7.8.5.2	7.8.5.3
7.8.5.4	7.8.5.5	7.8.5.6	7.8.5.7	7.8.5.8	7.8.5.9	7.8.6.1	7.8.6.2	7.8.6.3	7.8.6.4
7.8.6.5	7.8.6.6	7.8.6.7	7.8.6.8	7.8.6.9	7.8.7.1	7.8.7.2	7.8.7.3	7.8.7.4	7.8.7.5
7.8.7.6	7.8.7.7	7.8.7.8	7.8.7.9	7.8.8.1	7.8.8.2	7.8.8.3	7.8.8.4	7.8.8.5	7.8.8.6
7.8.8.7	7.8.8.8	7.8.8.9	7.8.9.1	7.8.9.2	7.8.9.3	7.8.9.4	7.8.9.5	7.8.9.6	7.8.9.7
7.8.9.8	7.8.9.9	7.9.1.1	7.9.1.2	7.9.1.3	7.9.1.4	7.9.1.5	7.9.1.6	7.9.1.7	7.9.1.8
7.9.1.9	7.9.2.1	7.9.2.2	7.9.2.3	7.9.2.4	7.9.2.5	7.9.2.6	7.9.2.7	7.9.2.8	7.9.2.9
7.9.3.1	7.9.3.2	7.9.3.3	7.9.3.4	7.9.3.5	7.9.3.6	7.9.3.7	7.9.3.8	7.9.3.9	7.9.4.1
7.9.4.2	7.9.4.3	7.9.4.4	7.9.4.5	7.9.4.6	7.9.4.7	7.9.4.8	7.9.4.9	7.9.5.1	7.9.5.2
7.9.5.3	7.9.5.4	7.9.5.5	7.9.5.6	7.9.5.7	7.9.5.8	7.9.5.9	7.9.6.1	7.9.6.2	7.9.6.3
7.9.6.4	7.9.6.5	7.9.6.6	7.9.6.7	7.9.6.8	7.9.6.9	7.9.7.1	7.9.7.2	7.9.7.3	7.9.7.4
7.9.7.5	7.9.7.6	7.9.7.7	7.9.7.8	7.9.7.9	7.9.8.1	7.9.8.2	7.9.8.3	7.9.8.4	7.9.8.5
7.9.8.6	7.9.8.7	7.9.8.8	7.9.8.9	7.9.9.1	7.9.9.2	7.9.9.3	7.9.9.4	7.9.9.5	7.9.9.6
7.9.9.7	7.9.9.8	7.9.9.9	8.1.1.1	8.1.1.2	8.1.1.3	8.1.1.4	8.1.1.5	8.1.1.6	8.1.1.7
8.1.1.8	8.1.1.9	8.1.2.1	8.1.2.2	8.1.2.3	8.1.2.4	8.1.2.5	8.1.2.6	8.1.2.7	8.1.2.8
8.1.2.9	8.1.3.1	8.1.3.2	8.1.3.3	8.1.3.4	8.1.3.5	8.1.3.6	8.1.3.7	8.1.3.8	8.1.3.9
8.1.4.1	8.1.4.2	8.1.4.3	8.1.4.4	8.1.4.5	8.1.4.6	8.1.4.7	8.1.4.8	8.1.4.9	8.1.5.1
8.1.5.2	8.1.5.3	8.1.5.4	8.1.5.5	8.1.5.6	8.1.5.7	8.1.5.8	8.1.5.9	8.1.6.1	8.1.6.2
8.1.6.3	8.1.6.4	8.1.6.5	8.1.6.6	8.1.6.7	8.1.6.8	8.1.6.9	8.1.7.1	8.1.7.2	8.1.7.3
8.1.7.4	8.1.7.5	8.1.7.6	8.1.7.7	8.1.7.8	8.1.7.9	8.1.8.1	8.1.8.2	8.1.8.3	8.1.8.4
8.1.8.5	8.1.8.6	8.1.8.7	8.1.8.8	8.1.8.9	8.1.9.1	8.1.9.2	8.1.9.3	8.1.9.4	8.1.9.5
8.1.9.6	8.1.9.7	8.1.9.8	8.1.9.9	8.2.1.1	8.2.1.2	8.2.1.3	8.2.1.4	8.2.1.5	8.2.1.6
8.2.1.7	8.2.1.8	8.2.1.9	8.2.2.1	8.2.2.2	8.2.2.3	8.2.2.4	8.2.2.5	8.2.2.6	8.2.2.7
8.2.2.8	8.2.2.9	8.2.3.1	8.2.3.2	8.2.3.3	8.2.3.4	8.2.3.5	8.2.3.6	8.2.3.7	8.2.3.8
8.2.3.9	8.2.4.1	8.2.4.2	8.2.4.3	8.2.4.4	8.2.4.5	8.2.4.6	8.2.4.7	8.2.4.8	8.2.4.9
8.2.5.1	8.2.5.2	8.2.5.3	8.2.5.4	8.2.5.5	8.2.5.6	8.2.5.7	8.2.5.8	8.2.5.9	8.2.6.1
8.2.6.2	8.2.6.3	8.2.6.4	8.2.6.5	8.2.6.6	8.2.6.7	8.2.6.8	8.2.6.9	8.2.7.1	8.2.7.2
8.2.7.3	8.2.7.4	8.2.7.5	8.2.7.6	8.2.7.7	8.2.7.8	8.2.7.9	8.2.8.1	8.2.8.2	8.2.8.3
8.2.8.4	8.2.8.5	8.2.8.6	8.2.8.7	8.2.8.8	8.2.8.9	8.2.9.1	8.2.9.2	8.2.9.3	8.2.9.4
8.2.9.5	8.2.9.6	8.2.9.7	8.2.9.8	8.2.9.9	8.3.1.1	8.3.1.2	8.3.1.3	8.3.1.4	8.3.1.5
8.3.1.6	8.3.1.7	8.3.1.8	8.3.1.9	8.3.2.1	8.3.2.2	8.3.2.3	8.3.2.4	8.3.2.5	8.3.2.6

Table 2- continued

8.3.2.7	8.3.2.8	8.3.2.9	8.3.3.1	8.3.3.2	8.3.3.3	8.3.3.4	8.3.3.5	8.3.3.6	8.3.3.7
8.3.3.8	8.3.3.9	8.3.4.1	8.3.4.2	8.3.4.3	8.3.4.4	8.3.4.5	8.3.4.6	8.3.4.7	8.3.4.8
8.3.4.9	8.3.5.1	8.3.5.2	8.3.5.3	8.3.5.4	8.3.5.5	8.3.5.6	8.3.5.7	8.3.5.8	8.3.5.9
8.3.6.1	8.3.6.2	8.3.6.3	8.3.6.4	8.3.6.5	8.3.6.6	8.3.6.7	8.3.6.8	8.3.6.9	8.3.7.1
8.3.7.2	8.3.7.3	8.3.7.4	8.3.7.5	8.3.7.6	8.3.7.7	8.3.7.8	8.3.7.9	8.3.8.1	8.3.8.2
8.3.8.3	8.3.8.4	8.3.8.5	8.3.8.6	8.3.8.7	8.3.8.8	8.3.8.9	8.3.9.1	8.3.9.2	8.3.9.3
8.3.9.4	8.3.9.5	8.3.9.6	8.3.9.7	8.3.9.8	8.3.9.9	8.4.1.1	8.4.1.2	8.4.1.3	8.4.1.4
8.4.1.5	8.4.1.6	8.4.1.7	8.4.1.8	8.4.1.9	8.4.2.1	8.4.2.2	8.4.2.3	8.4.2.4	8.4.2.5
8.4.2.6	8.4.2.7	8.4.2.8	8.4.2.9	8.4.3.1	8.4.3.2	8.4.3.3	8.4.3.4	8.4.3.5	8.4.3.6
8.4.3.7	8.4.3.8	8.4.3.9	8.4.4.1	8.4.4.2	8.4.4.3	8.4.4.4	8.4.4.5	8.4.4.6	8.4.4.7
8.4.4.8	8.4.4.9	8.4.5.1	8.4.5.2	8.4.5.3	8.4.5.4	8.4.5.5	8.4.5.6	8.4.5.7	8.4.5.8
8.4.5.9	8.4.6.1	8.4.6.2	8.4.6.3	8.4.6.4	8.4.6.5	8.4.6.6	8.4.6.7	8.4.6.8	8.4.6.9
8.4.7.1	8.4.7.2	8.4.7.3	8.4.7.4	8.4.7.5	8.4.7.6	8.4.7.7	8.4.7.8	8.4.7.9	8.4.8.1
8.4.8.2	8.4.8.3	8.4.8.4	8.4.8.5	8.4.8.6	8.4.8.7	8.4.8.8	8.4.8.9	8.4.9.1	8.4.9.2
8.4.9.3	8.4.9.4	8.4.9.5	8.4.9.6	8.4.9.7	8.4.9.8	8.4.9.9	8.5.1.1	8.5.1.2	8.5.1.3
8.5.1.4	8.5.1.5	8.5.1.6	8.5.1.7	8.5.1.8	8.5.1.9	8.5.2.1	8.5.2.2	8.5.2.3	8.5.2.4
8.5.2.5	8.5.2.6	8.5.2.7	8.5.2.8	8.5.2.9	8.5.3.1	8.5.3.2	8.5.3.3	8.5.3.4	8.5.3.5
8.5.3.6	8.5.3.7	8.5.3.8	8.5.3.9	8.5.4.1	8.5.4.2	8.5.4.3	8.5.4.4	8.5.4.5	8.5.4.6
8.5.4.7	8.5.4.8	8.5.4.9	8.5.5.1	8.5.5.2	8.5.5.3	8.5.5.4	8.5.5.5	8.5.5.6	8.5.5.7
8.5.5.8	8.5.5.9	8.5.6.1	8.5.6.2	8.5.6.3	8.5.6.4	8.5.6.5	8.5.6.6	8.5.6.7	8.5.6.8
8.5.6.9	8.5.7.1	8.5.7.2	8.5.7.3	8.5.7.4	8.5.7.5	8.5.7.6	8.5.7.7	8.5.7.8	8.5.7.9
8.5.8.1	8.5.8.2	8.5.8.3	8.5.8.4	8.5.8.5	8.5.8.6	8.5.8.7	8.5.8.8	8.5.8.9	8.5.9.1
8.5.9.2	8.5.9.3	8.5.9.4	8.5.9.5	8.5.9.6	8.5.9.7	8.5.9.8	8.5.9.9	8.6.1.1	8.6.1.2
8.6.1.3	8.6.1.4	8.6.1.5	8.6.1.6	8.6.1.7	8.6.1.8	8.6.1.9	8.6.2.1	8.6.2.2	8.6.2.3
8.6.2.4	8.6.2.5	8.6.2.6	8.6.2.7	8.6.2.8	8.6.2.9	8.6.3.1	8.6.3.2	8.6.3.3	8.6.3.4
8.6.3.5	8.6.3.6	8.6.3.7	8.6.3.8	8.6.3.9	8.6.4.1	8.6.4.2	8.6.4.3	8.6.4.4	8.6.4.5
8.6.4.6	8.6.4.7	8.6.4.8	8.6.4.9	8.6.5.1	8.6.5.2	8.6.5.3	8.6.5.4	8.6.5.5	8.6.5.6
8.6.5.7	8.6.5.8	8.6.5.9	8.6.6.1	8.6.6.2	8.6.6.3	8.6.6.4	8.6.6.5	8.6.6.6	8.6.6.7
8.6.6.8	8.6.6.9	8.6.7.1	8.6.7.2	8.6.7.3	8.6.7.4	8.6.7.5	8.6.7.6	8.6.7.7	8.6.7.8
8.6.7.9	8.6.8.1	8.6.8.2	8.6.8.3	8.6.8.4	8.6.8.5	8.6.8.6	8.6.8.7	8.6.8.8	8.6.8.9
8.6.9.1	8.6.9.2	8.6.9.3	8.6.9.4	8.6.9.5	8.6.9.6	8.6.9.7	8.6.9.8	8.6.9.9	8.7.1.1
8.7.1.2	8.7.1.3	8.7.1.4	8.7.1.5	8.7.1.6	8.7.1.7	8.7.1.8	8.7.1.9	8.7.2.1	8.7.2.2
8.7.2.3	8.7.2.4	8.7.2.5	8.7.2.6	8.7.2.7	8.7.2.8	8.7.2.9	8.7.3.1	8.7.3.2	8.7.3.3
8.7.3.4	8.7.3.5	8.7.3.6	8.7.3.7	8.7.3.8	8.7.3.9	8.7.4.1	8.7.4.2	8.7.4.3	8.7.4.4
8.7.4.5	8.7.4.6	8.7.4.7	8.7.4.8	8.7.4.9	8.7.5.1	8.7.5.2	8.7.5.3	8.7.5.4	8.7.5.5
8.7.5.6	8.7.5.7	8.7.5.8	8.7.5.9	8.7.6.1	8.7.6.2	8.7.6.3	8.7.6.4	8.7.6.5	8.7.6.6
8.7.6.7	8.7.6.8	8.7.6.9	8.7.7.1	8.7.7.2	8.7.7.3	8.7.7.4	8.7.7.5	8.7.7.6	8.7.7.7
8.7.7.8	8.7.7.9	8.7.8.1	8.7.8.2	8.7.8.3	8.7.8.4	8.7.8.5	8.7.8.6	8.7.8.7	8.7.8.8
8.7.8.9	8.7.9.1	8.7.9.2	8.7.9.3	8.7.9.4	8.7.9.5	8.7.9.6	8.7.9.7	8.7.9.8	8.7.9.9
8.8.1.1	8.8.1.2	8.8.1.3	8.8.1.4	8.8.1.5	8.8.1.6	8.8.1.7	8.8.1.8	8.8.1.9	8.8.2.1
8.8.2.2	8.8.2.3	8.8.2.4	8.8.2.5	8.8.2.6	8.8.2.7	8.8.2.8	8.8.2.9	8.8.3.1	8.8.3.2
8.8.3.3	8.8.3.4	8.8.3.5	8.8.3.6	8.8.3.7	8.8.3.8	8.8.3.9	8.8.4.1	8.8.4.2	8.8.4.3
8.8.4.4	8.8.4.5	8.8.4.6	8.8.4.7	8.8.4.8	8.8.4.9	8.8.5.1	8.8.5.2	8.8.5.3	8.8.5.4
8.8.5.5	8.8.5.6	8.8.5.7	8.8.5.8	8.8.5.9	8.8.6.1	8.8.6.2	8.8.6.3	8.8.6.4	8.8.6.5
8.8.6.6	8.8.6.7	8.8.6.8	8.8.6.9	8.8.7.1	8.8.7.2	8.8.7.3	8.8.7.4	8.8.7.5	8.8.7.6
8.8.7.7	8.8.7.8	8.8.7.9	8.8.8.1	8.8.8.2	8.8.8.3	8.8.8.4	8.8.8.5	8.8.8.6	8.8.8.7
8.8.8.8	8.8.8.9	8.8.9.1	8.8.9.2	8.8.9.3	8.8.9.4	8.8.9.5	8.8.9.6	8.8.9.7	8.8.9.8
8.8.9.9	8.9.1.1	8.9.1.2	8.9.1.3	8.9.1.4	8.9.1.5	8.9.1.6	8.9.1.7	8.9.1.8	8.9.1.9

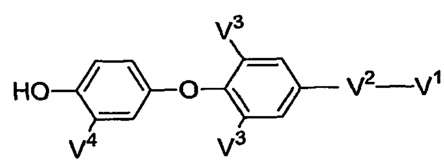
Table 2 - continued

8.9.2.1	8.9.2.2	8.9.2.3	8.9.2.4	8.9.2.5	8.9.2.6	8.9.2.7	8.9.2.8	8.9.2.9	8.9.3.1
8.9.3.2	8.9.3.3	8.9.3.4	8.9.3.5	8.9.3.6	8.9.3.7	8.9.3.8	8.9.3.9	8.9.4.1	8.9.4.2
8.9.4.3	8.9.4.4	8.9.4.5	8.9.4.6	8.9.4.7	8.9.4.8	8.9.4.9	8.9.5.1	8.9.5.2	8.9.5.3
8.9.5.4	8.9.5.5	8.9.5.6	8.9.5.7	8.9.5.8	8.9.5.9	8.9.6.1	8.9.6.2	8.9.6.3	8.9.6.4
8.9.6.5	8.9.6.6	8.9.6.7	8.9.6.8	8.9.6.9	8.9.7.1	8.9.7.2	8.9.7.3	8.9.7.4	8.9.7.5
8.9.7.6	8.9.7.7	8.9.7.8	8.9.7.9	8.9.8.1	8.9.8.2	8.9.8.3	8.9.8.4	8.9.8.5	8.9.8.6
8.9.8.7	8.9.8.8	8.9.8.9	8.9.9.1	8.9.9.2	8.9.9.3	8.9.9.4	8.9.9.5	8.9.9.6	8.9.9.7
8.9.9.8	8.9.9.9	9.1.1.1	9.1.1.2	9.1.1.3	9.1.1.4	9.1.1.5	9.1.1.6	9.1.1.7	9.1.1.8
9.1.1.9	9.1.2.1	9.1.2.2	9.1.2.3	9.1.2.4	9.1.2.5	9.1.2.6	9.1.2.7	9.1.2.8	9.1.2.9
9.1.3.1	9.1.3.2	9.1.3.3	9.1.3.4	9.1.3.5	9.1.3.6	9.1.3.7	9.1.3.8	9.1.3.9	9.1.4.1
9.1.4.2	9.1.4.3	9.1.4.4	9.1.4.5	9.1.4.6	9.1.4.7	9.1.4.8	9.1.4.9	9.1.5.1	9.1.5.2
9.1.5.3	9.1.5.4	9.1.5.5	9.1.5.6	9.1.5.7	9.1.5.8	9.1.5.9	9.1.6.1	9.1.6.2	9.1.6.3
9.1.6.4	9.1.6.5	9.1.6.6	9.1.6.7	9.1.6.8	9.1.6.9	9.1.7.1	9.1.7.2	9.1.7.3	9.1.7.4
9.1.7.5	9.1.7.6	9.1.7.7	9.1.7.8	9.1.7.9	9.1.8.1	9.1.8.2	9.1.8.3	9.1.8.4	9.1.8.5
9.1.8.6	9.1.8.7	9.1.8.8	9.1.8.9	9.1.9.1	9.1.9.2	9.1.9.3	9.1.9.4	9.1.9.5	9.1.9.6
9.1.9.7	9.1.9.8	9.1.9.9	9.2.1.1	9.2.1.2	9.2.1.3	9.2.1.4	9.2.1.5	9.2.1.6	9.2.1.7
9.2.1.8	9.2.1.9	9.2.2.1	9.2.2.2	9.2.2.3	9.2.2.4	9.2.2.5	9.2.2.6	9.2.2.7	9.2.2.8
9.2.2.9	9.2.3.1	9.2.3.2	9.2.3.3	9.2.3.4	9.2.3.5	9.2.3.6	9.2.3.7	9.2.3.8	9.2.3.9
9.2.4.1	9.2.4.2	9.2.4.3	9.2.4.4	9.2.4.5	9.2.4.6	9.2.4.7	9.2.4.8	9.2.4.9	9.2.5.1
9.2.5.2	9.2.5.3	9.2.5.4	9.2.5.5	9.2.5.6	9.2.5.7	9.2.5.8	9.2.5.9	9.2.6.1	9.2.6.2
9.2.6.3	9.2.6.4	9.2.6.5	9.2.6.6	9.2.6.7	9.2.6.8	9.2.6.9	9.2.7.1	9.2.7.2	9.2.7.3
9.2.7.4	9.2.7.5	9.2.7.6	9.2.7.7	9.2.7.8	9.2.7.9	9.2.8.1	9.2.8.2	9.2.8.3	9.2.8.4
9.2.8.5	9.2.8.6	9.2.8.7	9.2.8.8	9.2.8.9	9.2.9.1	9.2.9.2	9.2.9.3	9.2.9.4	9.2.9.5
9.2.9.6	9.2.9.7	9.2.9.8	9.2.9.9	9.3.1.1	9.3.1.2	9.3.1.3	9.3.1.4	9.3.1.5	9.3.1.6
9.3.1.7	9.3.1.8	9.3.1.9	9.3.2.1	9.3.2.2	9.3.2.3	9.3.2.4	9.3.2.5	9.3.2.6	9.3.2.7
9.3.2.8	9.3.2.9	9.3.3.1	9.3.3.2	9.3.3.3	9.3.3.4	9.3.3.5	9.3.3.6	9.3.3.7	9.3.3.8
9.3.3.9	9.3.4.1	9.3.4.2	9.3.4.3	9.3.4.4	9.3.4.5	9.3.4.6	9.3.4.7	9.3.4.8	9.3.4.9
9.3.5.1	9.3.5.2	9.3.5.3	9.3.5.4	9.3.5.5	9.3.5.6	9.3.5.7	9.3.5.8	9.3.5.9	9.3.6.1
9.3.6.2	9.3.6.3	9.3.6.4	9.3.6.5	9.3.6.6	9.3.6.7	9.3.6.8	9.3.6.9	9.3.7.1	9.3.7.2
9.3.7.3	9.3.7.4	9.3.7.5	9.3.7.6	9.3.7.7	9.3.7.8	9.3.7.9	9.3.8.1	9.3.8.2	9.3.8.3
9.3.8.4	9.3.8.5	9.3.8.6	9.3.8.7	9.3.8.8	9.3.8.9	9.3.9.1	9.3.9.2	9.3.9.3	9.3.9.4
9.3.9.5	9.3.9.6	9.3.9.7	9.3.9.8	9.3.9.9	9.4.1.1	9.4.1.2	9.4.1.3	9.4.1.4	9.4.1.5
9.4.1.6	9.4.1.7	9.4.1.8	9.4.1.9	9.4.2.1	9.4.2.2	9.4.2.3	9.4.2.4	9.4.2.5	9.4.2.6
9.4.2.7	9.4.2.8	9.4.2.9	9.4.3.1	9.4.3.2	9.4.3.3	9.4.3.4	9.4.3.5	9.4.3.6	9.4.3.7
9.4.3.8	9.4.3.9	9.4.4.1	9.4.4.2	9.4.4.3	9.4.4.4	9.4.4.5	9.4.4.6	9.4.4.7	9.4.4.8
9.4.4.9	9.4.5.1	9.4.5.2	9.4.5.3	9.4.5.4	9.4.5.5	9.4.5.6	9.4.5.7	9.4.5.8	9.4.5.9
9.4.6.1	9.4.6.2	9.4.6.3	9.4.6.4	9.4.6.5	9.4.6.6	9.4.6.7	9.4.6.8	9.4.6.9	9.4.7.1
9.4.7.2	9.4.7.3	9.4.7.4	9.4.7.5	9.4.7.6	9.4.7.7	9.4.7.8	9.4.7.9	9.4.8.1	9.4.8.2
9.4.8.3	9.4.8.4	9.4.8.5	9.4.8.6	9.4.8.7	9.4.8.8	9.4.8.9	9.4.9.1	9.4.9.2	9.4.9.3
9.4.9.4	9.4.9.5	9.4.9.6	9.4.9.7	9.4.9.8	9.4.9.9	9.5.1.1	9.5.1.2	9.5.1.3	9.5.1.4
9.5.1.5	9.5.1.6	9.5.1.7	9.5.1.8	9.5.1.9	9.5.2.1	9.5.2.2	9.5.2.3	9.5.2.4	9.5.2.5
9.5.2.6	9.5.2.7	9.5.2.8	9.5.2.9	9.5.3.1	9.5.3.2	9.5.3.3	9.5.3.4	9.5.3.5	9.5.3.6
9.5.3.7	9.5.3.8	9.5.3.9	9.5.4.1	9.5.4.2	9.5.4.3	9.5.4.4	9.5.4.5	9.5.4.6	9.5.4.7
9.5.4.8	9.5.4.9	9.5.5.1	9.5.5.2	9.5.5.3	9.5.5.4	9.5.5.5	9.5.5.6	9.5.5.7	9.5.5.8
9.5.5.9	9.5.6.1	9.5.6.2	9.5.6.3	9.5.6.4	9.5.6.5	9.5.6.6	9.5.6.7	9.5.6.8	9.5.6.9
9.5.7.1	9.5.7.2	9.5.7.3	9.5.7.4	9.5.7.5	9.5.7.6	9.5.7.7	9.5.7.8	9.5.7.9	9.5.8.1
9.5.8.2	9.5.8.3	9.5.8.4	9.5.8.5	9.5.8.6	9.5.8.7	9.5.8.8	9.5.8.9	9.5.9.1	9.5.9.2
9.5.9.3	9.5.9.4	9.5.9.5	9.5.9.6	9.5.9.7	9.5.9.8	9.5.9.9	9.6.1.1	9.6.1.2	9.6.1.3

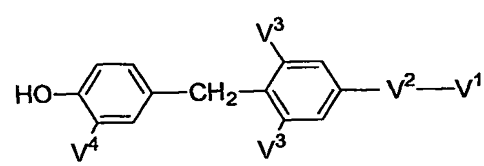
Table 2 - continued

9.6.1.4	9.6.1.5	9.6.1.6	9.6.1.7	9.6.1.8	9.6.1.9	9.6.2.1	9.6.2.2	9.6.2.3	9.6.2.4
9.6.2.5	9.6.2.6	9.6.2.7	9.6.2.8	9.6.2.9	9.6.3.1	9.6.3.2	9.6.3.3	9.6.3.4	9.6.3.5
9.6.3.6	9.6.3.7	9.6.3.8	9.6.3.9	9.6.4.1	9.6.4.2	9.6.4.3	9.6.4.4	9.6.4.5	9.6.4.6
9.6.4.7	9.6.4.8	9.6.4.9	9.6.5.1	9.6.5.2	9.6.5.3	9.6.5.4	9.6.5.5	9.6.5.6	9.6.5.7
9.6.5.8	9.6.5.9	9.6.6.1	9.6.6.2	9.6.6.3	9.6.6.4	9.6.6.5	9.6.6.6	9.6.6.7	9.6.6.8
9.6.6.9	9.6.7.1	9.6.7.2	9.6.7.3	9.6.7.4	9.6.7.5	9.6.7.6	9.6.7.7	9.6.7.8	9.6.7.9
9.6.8.1	9.6.8.2	9.6.8.3	9.6.8.4	9.6.8.5	9.6.8.6	9.6.8.7	9.6.8.8	9.6.8.9	9.6.9.1
9.6.9.2	9.6.9.3	9.6.9.4	9.6.9.5	9.6.9.6	9.6.9.7	9.6.9.8	9.6.9.9	9.7.1.1	9.7.1.2
9.7.1.3	9.7.1.4	9.7.1.5	9.7.1.6	9.7.1.7	9.7.1.8	9.7.1.9	9.7.2.1	9.7.2.2	9.7.2.3
9.7.2.4	9.7.2.5	9.7.2.6	9.7.2.7	9.7.2.8	9.7.2.9	9.7.3.1	9.7.3.2	9.7.3.3	9.7.3.4
9.7.3.5	9.7.3.6	9.7.3.7	9.7.3.8	9.7.3.9	9.7.4.1	9.7.4.2	9.7.4.3	9.7.4.4	9.7.4.5
9.7.4.6	9.7.4.7	9.7.4.8	9.7.4.9	9.7.5.1	9.7.5.2	9.7.5.3	9.7.5.4	9.7.5.5	9.7.5.6
9.7.5.7	9.7.5.8	9.7.5.9	9.7.6.1	9.7.6.2	9.7.6.3	9.7.6.4	9.7.6.5	9.7.6.6	9.7.6.7
9.7.6.8	9.7.6.9	9.7.7.1	9.7.7.2	9.7.7.3	9.7.7.4	9.7.7.5	9.7.7.6	9.7.7.7	9.7.7.8
9.7.7.9	9.7.8.1	9.7.8.2	9.7.8.3	9.7.8.4	9.7.8.5	9.7.8.6	9.7.8.7	9.7.8.8	9.7.8.9
9.7.9.1	9.7.9.2	9.7.9.3	9.7.9.4	9.7.9.5	9.7.9.6	9.7.9.7	9.7.9.8	9.7.9.9	9.8.1.1
9.8.1.2	9.8.1.3	9.8.1.4	9.8.1.5	9.8.1.6	9.8.1.7	9.8.1.8	9.8.1.9	9.8.2.1	9.8.2.2
9.8.2.3	9.8.2.4	9.8.2.5	9.8.2.6	9.8.2.7	9.8.2.8	9.8.2.9	9.8.3.1	9.8.3.2	9.8.3.3
9.8.3.4	9.8.3.5	9.8.3.6	9.8.3.7	9.8.3.8	9.8.3.9	9.8.4.1	9.8.4.2	9.8.4.3	9.8.4.4
9.8.4.5	9.8.4.6	9.8.4.7	9.8.4.8	9.8.4.9	9.8.5.1	9.8.5.2	9.8.5.3	9.8.5.4	9.8.5.5
9.8.5.6	9.8.5.7	9.8.5.8	9.8.5.9	9.8.6.1	9.8.6.2	9.8.6.3	9.8.6.4	9.8.6.5	9.8.6.6
9.8.6.7	9.8.6.8	9.8.6.9	9.8.7.1	9.8.7.2	9.8.7.3	9.8.7.4	9.8.7.5	9.8.7.6	9.8.7.7
9.8.7.8	9.8.7.9	9.8.8.1	9.8.8.2	9.8.8.3	9.8.8.4	9.8.8.5	9.8.8.6	9.8.8.7	9.8.8.8
9.8.8.9	9.8.9.1	9.8.9.2	9.8.9.3	9.8.9.4	9.8.9.5	9.8.9.6	9.8.9.7	9.8.9.8	9.8.9.9
9.9.1.1	9.9.1.2	9.9.1.3	9.9.1.4	9.9.1.5	9.9.1.6	9.9.1.7	9.9.1.8	9.9.1.9	9.9.2.1
9.9.2.2	9.9.2.3	9.9.2.4	9.9.2.5	9.9.2.6	9.9.2.7	9.9.2.8	9.9.2.9	9.9.3.1	9.9.3.2
9.9.3.3	9.9.3.4	9.9.3.5	9.9.3.6	9.9.3.7	9.9.3.8	9.9.3.9	9.9.4.1	9.9.4.2	9.9.4.3
9.9.4.4	9.9.4.5	9.9.4.6	9.9.4.7	9.9.4.8	9.9.4.9	9.9.5.1	9.9.5.2	9.9.5.3	9.9.5.4
9.9.5.5	9.9.5.6	9.9.5.7	9.9.5.8	9.9.5.9	9.9.6.1	9.9.6.2	9.9.6.3	9.9.6.4	9.9.6.5
9.9.6.6	9.9.6.7	9.9.6.8	9.9.6.9	9.9.7.1	9.9.7.2	9.9.7.3	9.9.7.4	9.9.7.5	9.9.7.6
9.9.7.7	9.9.7.8	9.9.7.9	9.9.8.1	9.9.8.2	9.9.8.3	9.9.8.4	9.9.8.5	9.9.8.6	9.9.8.7
9.9.8.8	9.9.8.9	9.9.9.1	9.9.9.2	9.9.9.3	9.9.9.4	9.9.9.5	9.9.9.6	9.9.9.7	9.9.9.8
9.9.9.9									

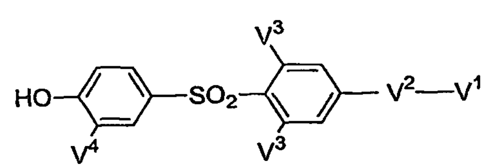
In another aspect the following compounds are included in the invention but the compounds are not limited to these illustrative compounds. The compounds are shown without depiction of stereochemistry since the compounds are biologically active as the diastereomeric mixture or as a single stereoisomer. Compounds included are designated by numbers assigned to the variables of formulas XI - XIII using the following convention: V1.V2.V3.V4. V5.V6. Each individual compound from 1.1.1.1.1.1 to 9.9.9.9.9.9 (e.g., 2.3.4.5.6.7. or 8.7.3.5.2.1) is included in the present invention as an individual species and may be specifically set forth as such for inclusion or may be specifically excluded from the present invention. As the understanding is to what is included is clear from the description thus, a Table is not included so as to not unduly lengthen the specification.



Formula XI



Formula XII



Formula XIII

Variable V^1:

1) $-P(O)(OH)_2$
2) $-P(O)[O-CH_2OC(O)C(CH_3)_3]_2$
3) $-P(O)[O-CH_2OC(O)CH(CH_3)_2]_2$
4) $-P(O)[O-CH_2OC(O)OCH_2CH_3]_2$
5) $-P(O)[NH-CH(CH_3)C(O)OCH_2CH_3]_2$
6) $-P(O)[NH-C(CH_3)_2C(O)OCH_2CH_3]_2$
7) $-P(O)(OC_6H_5)_2$
8) -P(O)(O-CH(3-chlorophenyl)CH_2CH_2-O)
9) -P(O)(O-CH(4-pyridyl)CH_2CH_2-O)

Variable V^2:

1) $-CH_2-$
2) $-OCH_2-$
3) $-CH_2-CH_2-$
4) $-NHCH_2-$
5) -NH(CO)-
6) $-CH_2-CH(NH_2)-$ (*R*-configuration)
7) $-CH_2-CH(NH_2)-$ (*S*-configuration)
8) -CH=CH- (*trans*)
9) - null

Variable V^3:

1) $-OCH_3$
2) iodo
3) bromo
4) chloro
5) fluoro
6) methyl
7) trifluoromethyl
8) cyano
9) $-OCF_3$

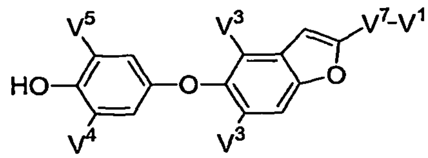
Variable V^4:

1) iodo
2) $CH(CH_3)_2$
3) -(3-trifluoromethylphenoxy)
4) -(3-ethylphenyl)
5) -C(O)NH-CH_2-CH_2-phenyl
6) -CH(OH)(4-fluorophenyl)
7) -SO_2(4-fluorophenyl)
8) -(4-fluorobenzyl)
9) -1-ethyl-propyl

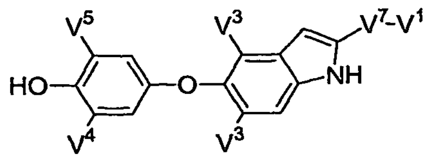
Variable V^5 and V^6

1) hydrogen
2) iodo
3) bromo
4) chloro
5) fluoro
6) methyl
7) trifluoromethyl
8) cyano
9) -OCH_3

In another aspect the following compounds are included in the invention but the compounds are not limited to these illustrative compounds. The compounds are shown without depiction of stereochemistry since the compounds are biologically active as the diastereomeric mixture or as a single stereoisomer. Compounds included are designated by numbers assigned to the variables of formulas XIV and XV using the following convention: $V^1.V^2.V^3.V^4.\ V^5.V^6.\ V^7$ Each individual compound from 1.1.1.1.1.1.1 to 9.9.9.9.9.9. 2(e.g., 2.3.4.5.6.7.1 or 8.7.3.5.2.1.1) is included in the present invention as an individual species and may be specifically set forth as such for inclusion or may be specifically excluded from the present invention. As the understanding is to what is included is clear from the description thus, a Table is not included so as to not unduly lengthen the specification.



Formula XIV



Formula XV

Variable V^7:

1) $-CH_2-$
2) - null

The present invention provides for compounds of Formula I including but not limited to wherein:

Phosphonic Acids

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-PO_3H_2$;

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -I, R^5 is -OH, X is $-PO_3H_2$;

G is -O-, T is $-CH_2-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-PO_3H_2$;

G is -O-, T is -N(H)C(O)-, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is CH(OH) (4-fluorophenyl), R^4 is -H, R^5 is -OH, X is $-PO_3H_2$;

G is $-CH_2-$, T is $-OCH_2-$, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is *i*-propyl, R^4 is -H, R^5 is -OH, X is $-PO_3H_2$;

G is -O-, T is $-CH_2-$, R^1 is -Cl, R^2 is -Cl, R^3 is *i*-propyl, R^4 is -H, R^5 is -OH, X is $-PO_3H_2$;

G is -O-, T is $-OCH_2-$, R^1 is -I, R^2 is -I, R^3 is i-propyl, R^4 is -H, R^5 is -OH, X is PO_3H_2;

BisPOM

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)C(CH_3)_3]_2$;

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -I, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)C(CH_3)_3]_2$;

G is -O-, T is $-CH_2-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)C(CH_3)_3]_2$;

G is -O-, T is -N(H)C(O)-, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is CH(OH)(4-fluorophenyl), R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)C(CH_3)_3]_2$;

G is $-CH_2-$, T is $-OCH_2-$, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is *i*-propyl, R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)C(CH_3)_3]_2$;

G is -O-, T is $-CH_2-$, R^1 is -Cl, R^2 is -Cl, R^3 is *i*-propyl, R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)C(CH_3)_3]_2$;

G is -O-, T is $-OCH_2-$, R^1 is -I, R^2 is -I, R^3 is i-propyl, R^4 is -H, R^5 is -OH, X is PO_3H_2;

Carbonates

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)OCH(CH_3)_2]_2$;

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -I, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)OCH(CH_3)_2]_2$;

G is -O-, T is $-CH_2-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)OCH(CH_3)_2]_2$;

G is -O-, T is -N(H)C(O)-, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is CH(OH)(4-fluorophenyl), R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)OCH(CH_3)_2]_2$;

G is $-CH_2-$, T is $-OCH_2-$, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is *i*-propyl, R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)OCH(CH_3)_2]_2$;

G is -O-, T is $-CH_2-$, R^1 is -Cl, R^2 is -Cl, R^3 is *i*-propyl, R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH_2OC(O)OCH(CH_3)_2]_2$;

G is -O-, T is $-OCH_2-$, R^1 is -I, R^2 is -I, R^3 is i-propyl, R^4 is -H, R^5 is -OH, X is PO_3H_2;

Bisamidates

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-P(O)[N(H)CH(CH_3)C(O)OCH_2CH_3]_2$;

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -I, R^5 is -OH, X is $-P(O)[N(H)CH(CH_3)C(O)OCH_2CH_3]_2$;

G is -O-, T is $-CH_2-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-P(O)[N(H)CH(CH_3)C(O)OCH_2CH_3]_2$;

G is -O-, T is -N(H)C(O)-, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is CH(OH) (4-fluorophenyl), R^4 is -H, R^5 is -OH, X is $-P(O)[N(H)CH(CH_3)C(O)OCH_2CH_3]_2$;

G is $-CH_2-$, T is $-OCH_2-$, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is *i*-propyl, R^4 is -H, R^5 is -OH, X is $-P(O)[N(H)CH(CH_3)C(O)OCH_2CH_3]_2$;

G is -O-, T is $-CH_2-$, R^1 is -Cl, R^2 is -Cl, R^3 is *i*-propyl, R^4 is -H, R^5 is -OH, X is $-P(O)[N(H)CH(CH_3)C(O)OCH_2CH_3]_2$;

G is -O-, T is $-OCH_2-$, R^1 is -I, R^2 is -I, R^3 is i-propyl, R^4 is -H, R^5 is -OH, X is PO_3H_2;

Bisamidates #2

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-P(O)[N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$;

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -I, R^5 is -OH, X is $-P(O)[N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$;

G is -O-, T is $-CH_2-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-P(O)[N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$;

G is -O-, T is -N(H)C(O)-, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is CH(OH) (4-fluorophenyl), R^4 is -H, R^5 is -OH, X is $-P(O)[N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$;

G is $-CH_2-$, T is $-OCH_2-$, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is *i*-propyl, R^4 is -H, R^5 is -OH, X is $-P(O)[N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$;

G is -O-, T is $-CH_2-$, R^1 is -Cl, R^2 is -Cl, R^3 is *i*-propyl, R^4 is -H, R^5 is -OH, X is $-P(O)[N(H)C(CH_3)_2C(O)OCH_2CH_3]_2$;

G is -O-, T is $-OCH_2-$, R^1 is -I, R^2 is -I, R^3 is i-propyl, R^4 is -H, R^5 is -OH, X is PO_3H_2;

4-aryl-2-oxo-2-λ^5-1,3,2-dioxaphosphonanes

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH(3\text{-chlorophenyl})CH_2CH_2O-]$;

G is -O-, T is $-CH_2CH(NH_2)-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -I, R^5 is -OH, X is $-P(O)[-OCH(3\text{-chlorophenyl})CH_2CH_2O-]$;

G is -O-, T is $-CH_2-$, R^1 is -I, R^2 is -I, R^3 is -I, R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH(3\text{-chlorophenyl})CH_2CH_2O-]$;

G is -O-, T is -N(H)C(O)-, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is CH(OH) (4-fluorophenyl), R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH(3\text{-chlorophenyl})CH_2CH_2O-]$;

G is $-CH_2-$, T is $-OCH_2-$, R^1 is $-CH_3$, R^2 is $-CH_3$, R^3 is *i*-propyl, R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH(3\text{-chlorophenyl})CH_2CH_2O-]$;

G is -O-, T is $-CH_2-$, R^1 is -Cl, R^2 is -Cl, R^3 is *i*-propyl,'R^4 is -H, R^5 is -OH, X is $-P(O)[-OCH(3\text{-chlorophenyl})CH_2CH_2O-]$;

G is -O-, T is $-OCH_2-$, R^1 is -I, R^2 is -I, R^3 is i-propyl, R^4 is -H, R^5 is -OH, X is PO_3H_2;

Moreover, the compounds of the present invention can be administered in combination with other pharmaceutical agents that are used to lower serum cholesterol such as a cholesterol biosynthesis inhibitor or a cholesterol absorption inhibitor, especially a HMG-CoA reductase inhibitor, or a HMG-CoA synthase inhibitor, or a HMG-CoA reductase or synthase gene expression inhibitor, a cholesteryl ester transfer protein (CETP) inhibitor (e.g., torcetrapib), a bile acid sequesterant (e.g., cholestyramine (Questran®), colesevelam and colestipol (Colestid®)), or a bile acid reabsorption inhibitor (see, for example, U.S. Pat. No. 6,245,744, U.S. Pat. No. 6,221,897, U.S. Pat. No. 6,277,831, EP 0683 773, EP 0683 774), a cholesterol absorption inhibitor as described (e.g., ezetimibe, tiqueside, pamaqueside or see, e.g., in WO 0250027), a PPARalpha agonist, a mixed PPAR alpha/gamma agonist such as, for example, AZ 242 (Tesaglitazar, (S)-3-(4-[2-(4-methanesulfony- loxyphenyl)ethoxy]phenyl)-2-ethoxypropionic acid), BMS 298585 (N-[(4-methoxyphenoxy)carbonyl]-N-[[4-[2-(5-methyl-2-phenyl-4-oxazolyl)et- hoxy]phenyl]methyl]glycine) or as described in WO 99/62872, WO 99/62871, WO 01/40171, WO 01/40169, WO96/38428, WO 01/81327, WO 01/21602, WO 03/020269, WO 00/64888 or WO 00/64876, a MTP inhibitor such as, for example, implitapide, a fibrate, an ACAT inhibitors (e.g., avasimibe), an angiotensin II receptor antagonist, a squalene synthetase inhibitor, a squalene epoxidase inhibitor, a squalene cyclase inhibitor, combined squalene epoxidase/squalene cyclase

inhibitor, a lipoprotein lipase inhibitor, an ATP citrate lyase inhibitor, lipoprotein(a) antagonist, an antioxidant or niacin (e.g., slow release niacin). The compounds of the present invention may also be administered in combination with a naturally occurring compound that act to lower plasma cholesterol levels. Such naturally occurring compounds are commonly called nutraceuticals and include, for example, garlic extract and niacin.

In one aspect, the HMG-CoA reductase inhibitor is from a class of therapeutics commonly called statins. Examples of HMG-CoA reductase inhibitors that may be used include but are not limited to lovastatin (MEVACOR; see U.S. Pat. Nos. 4,231,938; 4,294,926; 4,319,039), simvastatin (ZOCOR; see U.S. Pat. Nos. 4,444,784; 4,450,171, 4,820,850; 4,916,239), pravastatin (PRAVACHOL; see U.S. Pat. Nos. 4,346,227; 4,537,859; 4,410,629; 5,030,447 and 5,180,589), lactones of pravastatin (see U.S. Pat. No. 4,448,979), fluvastatin (LESCOL; see U.S. Pat. Nos. 5,354,772; 4,911,165; 4,739,073; 4,929,437; 5,189,164; 5,118,853; 5,290,946; 5,356,896), lactones of fluvastatin, atorvastatin (LIPITOR; see U.S. Pat. Nos. 5,273,995; 4,681,893; 5,489,691; 5,342,952), lactones of atorvastatin, cerivastatin (also known as rivastatin and BAYCHOL; see U.S. Pat. No. 5,177,080, and European Application No. EP-491226A), lactones of cerivastatin, rosuvastatin (Crestor; see U.S. Pat. Nos. 5,260,440 and RE37314, and European Patent No. EP521471), lactones of rosuvastatin, itavastatin, nisvastatin, visastatin, atavastatin, bervastatin, compactin, dihydrocompactin, dalvastatin, fluindostatin, pitivastatin, mevastatin (see U.S. Pat. No. 3,983,140), and velostatin (also referred to as synvinolin). Other examples of HMG-CoA reductase inhibitors are described in U.S. Pat. Nos. 5,217,992; 5,196,440; 5,189,180; 5,166,364; 5,157,134; 5,110,940; 5,106,992; 5,099,035; 5,081,136; 5,049,696; 5,049,577; 5,025,017; 5,011,947; 5,010,105; 4,970,221; 4,940,800; 4,866,058; 4,686,237; 4,647,576; European Application Nos. 0142146A2 and 0221025A1; and PCT Application Nos. WO 86/03488 and WO 86/07054. Also included are pharmaceutically acceptable forms of the above. All of the above references are incorporated herein by reference.

Non-limiting examples of suitable bile acid sequestrants include cholestyramine (a styrene-divinylbenzene copolymer containing quaternary ammonium cationic groups capable of binding bile acids, such as QUESTRAN or QUESTRAN LIGHT cholestyramine which are available from Bristol-Myers Squibb), colestipol (a copolymer of diethylenetriamine and 1-chloro-2,3-epoxypropane, such as COLESTID tablets which are available from Pharmacia), colesevelam hydrochloride (such as WelChol Tablets

(poly(allylamine hydrochloride) cross-linked with epichlorohydrin and alkylated with 1-bromodecane and (6-bromohexyl)-trimethylammonium bromide) which are available from Sankyo), water soluble derivatives such as 3,3-ioene, N-(cycloalkyl)alkylamines and poliglusam, insoluble quaternized polystyrenes, saponins and mixtures thereof. Other useful bile acid sequestrants are disclosed in PCT Patent Applications Nos. WO 97/11345 and WO 98/57652, and U.S. Pat. Nos. 3,692,895 and 5,703,188 which are incorporated herein by reference. Suitable inorganic cholesterol sequestrants include bismuth salicylate plus montmorillonite clay, aluminum hydroxide and calcium carbonate antacids.

In the above description, a fibrate base compound is a medicament for inhibiting synthesis and secretion of triglycerides in the liver and activating lipoprotein lipase, thereby lowering the triglyceride level in the blood. Examples include bezafibrate, beclobrate, binifibrate, ciprofibrate, clinofibrate, clofibrate, clofibric acid, ethofibrate, fenofibrate, gemfibrozil, nicofibrate, pirifibrate, ronifibrate, simfibrate and theofibrate. Such an ACAT inhibitor includes, for example: a compound having the general formula (I) disclosed in WO 92/09561 [preferably FR-129169, of which the chemical name is N-(1,2-diphenylethyl)-2-(2-octyloxyphenyl)acetamide]; a compound having the general formula (I) including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in the Japanese Patent Publication (Kohyo) Hei 8-510256 (WO 94/26702, U.S. Pat. No. 5,491,172) {preferably CI-1011, of which the chemical name is 2,6-diisopropylphenyl-N-[(2,4,6-tr- iisopropylphenyl)acetyl]sulfamate, and in the present invention CI-1011 including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof; a compound having the general formula (I) including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in EP 421441 (U.S. Pat. No. 5,120,738) {preferably F-1394, of which the chemical name is (1S,2S)-2-[3-(2,2-dimet- hylpropyl)-3-nonylureido]cyclohexan-1-yl 3-[(4R)-N-(2,2,5,5-tetramethyl-1,- 3-dioxane-4-carbonyl)amino]propionate, and in the present invention F-1394 including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof }; a compound including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in the Japanese Patent Publication (Kohyo) 2000-500771 (WO 97/19918, U.S. Pat. No. 5,990,173) [preferably F-12511, of which the chemical name is (S)-2',3',5'-trimethyl-4'-hydroxy-.alpha.-dodecylthio-.alpha.-phenylaceta- nilide, and in the present invention F-12511 including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof.]; a compound having the general formula (I) including a

pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in the Japanese Patent Publication (Kokai) Hei 10-195037 (EP 790240, U.S. Pat. No. 5,849,732) [preferably T-2591, of which the chemical name is 1-(3-t-butyl-2-hydroxy-5-methoxyphenyl)-3-(2-cyclohexylethyl)-3-(4-dimethylaminophenyl)urea, and in the present invention T-2591 including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof.]; a compound having the general formula (I) including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in WO 96/26948 {preferably FCE-28654, of which the chemical name is 1-(2,6-diisopropylphenyl)-3-[(4R,5R)-4,5-di- methyl-2-(4-phosphonophenyl)-1,3-dioxolan-2-ylmethyl]urea, including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof.}; a compound having the general formula (I) or a pharmacologically acceptable salt thereof disclosed in the specification of WO 98/54153 (EP 987254) {preferably K-10085, of which the chemical name is N-[2,4-bis(methylthio)-6-methyl-3-pyridyl]-2-[4-[2-(oxazolo[4,5-b]pyridine-2-ylthio)ethyl]piperazin-1-yl]acetamide, including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof.}; a compound having the general formula (I) disclosed in WO 92/09572 (EP 559898, U.S. Pat. No. 5,475,130) [preferably HL-004, of which the chemical name is N-(2,6-diisopropylphenyl)-2-tetradecylthioacetamide.]; a compound having the general formula (I) including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in the Japanese Patent Publication (Kokai) Hei 7-82232 (EP 718281) {preferably NTE-122, of which the chemical name is trans-1,4-bis[1-cyclohexyl-3-(4-dimethylaminophenyl)urei- domethyl]cyclohexane, and in the present invention NTE-122 includes pharmacologically acceptable salts of NTE-122.}; a compound including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in the Japanese Patent Publication (Kohyo) Hei 10-510512 (WO 96/10559) {preferably FR-186054, of which the chemical name is 1-benzyl-1-[3-(pyrazol-3-yl)benzyl]-3-[2,4-bis(methylthio)-6-methylpyridi- n-3-yl]urea, and in the present invention FR-186054 including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof.}; a compound having the general formula (I) including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in WO 96/09287 (EP 0782986, U.S. Pat. No. 5,990,150) [preferably N-(1-pentyl-4,6-dimethylindolin-7-yl)-2,2-dimethylpropaneamide, and in the present invention including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof.]; and a compound having the general formula (I) including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof

disclosed in WO 97/12860 (EP 0866059, U.S. Pat. No. 6,063,806) [preferably N-(1-octyl-5-carboxymethyl-4,6-dimethylindolin- -7-yl)-2,2-dimethylpropaneamide, including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof.]. The ACAT inhibitor preferably is a compound selected from the group consisting of FR-129169, CI-1011, F-1394, F-12511, T-2591, FCE-28654, K-10085, HL-004, NTE-122, FR-186054, N-(1-octyl-5-carboxymethyl-4,6-dimet- hylindolin-7-yl)-2,2-dimethylpropaneamide (hereinafter referred as compound A), and N-(1-pentyl-4,6-dimethylindolin-7-yl)-2,2-dimethylpropan- eamide (hereinafter referred as compound B), including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof. The ACAT inhibitor more preferably is a compound selected from the group consisting of CI-1011, F-12511, N-(1-octyl-5-carboxymethyl-4,6-dime- thylindolin-7-yl)-2,2-dimethylpropaneamide (compound A), and N-(1-pentyl-4,6-dimethylindolin-7-yl)-2,2-dimethylpropaneamide (compound B), including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof; most preferred is N-(1-octyl-5-carboxymethyl-4,6-dimethylindolin-7-yl)-2,2-dimethylpropanea- mide (compound A).

An angiotensin II receptor antagonist includes, for example, a biphenyl tetrazole compound or biphenylcarboxylic acid derivative such as: a compound having the general formula (I) including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in the Japanese Patent Publication (Kokai) Sho 63-23868 (U.S. Pat. No. 5,138,069) {preferably losartan, of which the chemical name is 2-butyl-4-chloro-1-[2'-(1H-tetrazol-5-yl)biphe- nyl-4-ylmethyl]-1H-imidazol-5-methanol, and in the present invention losartan including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof }; a compound having the general formula (I) including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in the Japanese Patent Publication (Kohyo) Hei 4-506222 (WO 91/14679) {preferably irbesartan, of which the chemical name is 2-N-butyl-4-spirocyclopentane-1-[2'-(1H-tetrazol-5-yl)bi- phenyl-4-ylmethyl]-2-imidazoline-5-one, and in the present invention irbesartan including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof.}; a compound having the general formula (I), an ester thereof, including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in the Japanese Patent Publication (Kokai) Hei 4-235149 (EP 433983) {preferably valsartan, of which the chemical name is (S)-N-valeryl-N-[2'-(1H-tetrazol- -5-yl)biphenyl-4-ylmethyl]valine, and in the present invention valsartan including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof.}; a carboxylic acid derivative having

the general formula (I), including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in the Japanese Patent Publication (Kokai) Hei 4-364171 (U.S. Pat. No. 5,196,444) {preferably candesartan, of which the chemical name is 1-(cyclohexyloxycarbonyloxy)ethyl 2-ethoxy-1-[2'-(1H-tetrazol-5-yl)biphen- yl-4-ylmethyl]-1H-benzimidazole-7-carboxylate, and in the present invention candesartan including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof (TCV-116 or the like), including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof.}; a carboxylic acid derivative having the general formula (I), including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in the Japanese Patent Publication (Kokai) Hei 5-78328 (U.S. Pat. No. 5,616,599) {preferably olmesartan, of which the chemical name is (5-methyl-2-oxo-1,3-dioxolen-4-yl)methyl 4-(1-hydroxy-1-methylethyl)-2-pr- opyl-1-[2'-(1H-tetrazol-5-yl)biphenyl-4-ylmethyl]imidazole-5-carboxylate, and in the present invention olmesartan includes carboxylic acid derivatives thereof, pharmacologically acceptable esters of the carboxylic acid derivatives (CS-866 or the like), including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof }; and a compound having the general formula (I), including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof disclosed in the Japanese Patent Publication (Kokai) Hei 4-346978 (U.S. Pat. No. 5,591,762, EP 502,314) {preferably telmisartan, of which the chemical name is 4'-[[2-n-propyl-4-methyl-6-(1-methylbenzimidazol-2-yl)-benzimidazol-1-yl]- methyl]biphenyl-2-carboxylate, including a pharmacologically acceptable salt/co-crystal, ester or prodrug thereof }. The angiotensin II receptor antagonist preferably is losartan, irbesartan, valsartan, candesartan, olmesartan, or telmisartan; more preferred is losartan or olmesartan; and most preferred is olmesartan.

In addition to being useful in treating or preventing certain diseases and disorders, combination therapy with compounds of this invention maybe useful in reducing the dosage of the second drug or agent (*e.g.*, atorvastatin).

In addition, the compounds of the present invention can be used in combination with an apolipoprotein B secretion inhibitor and/or microsomal triglyceride transfer protein (MTP) inhibitor. Some apolipoprotein B secretion inhibitors and/or MTP inhibitors are disclosed in U.S. 5,919,795.

Any HMG-CoA reductase inhibitor may be employed as an additional compound in the combination therapy aspect of the present invention. The term HMG-CoA reductase inhibitor refers to a compound that inhibits the biotransformation of

hydroxymethylglutaryl-coenzyme A to mevalonic acid as catalyzed by the enzyme HMG-CoA reductase. Such inhibition may be determined readily by one of skill in the art according to standard assays (*e.g., Methods* of *Enzymology,* 71: 455—509 (1981); and the references cited therein). A variety of these compounds are described and referenced below. U.S. 4,231,938 discloses certain compounds isolated after cultivation of a microorganism belonging to the genus Aspergillus, such as lovastatin. Also U.S. 4,444,784 discloses synthetic derivatives of the aforementioned compounds, such as simvastatin. Additionally, U.S. 4,739,073 discloses certain substituted indoles, such as fluvastatin. Further, U.S. 4,346,227 discloses ML-236B derivatives, such as pravastatin. In addition, EP 491,226 teaches certain pyridyldihydroxyheptenoic acids, such as rivastatin. Also, U.S. 4,647,576 discloses certain 6-[2-(substituted-pyrrol-1-yl)-alkyl]-pyran-2-ones such as atorvastatin. Other HMG-CoA reductase inhibitors will be known to those skilled in the art. Examples of currently or previously marketed products containing HMG-CoA reductase inhibitors include cerivastatin Na, rosuvastatin Ca, fluvastatin, atorvastatin, lovastatin, pravastatin Na and simvastatin.

Any HMG-CoA synthase inhibitor may be used as an additional compound in the combination therapy aspect of this invention. The term HMG-CoA synthase inhibitor refers to a compound that inhibits the biosynthesis of hydroxymethylglutaryl-coenzyme A from acetyl-coenzyme A and acetoacetyl-coenzyme A, catalyzed by the enzyme HMG-CoA synthase. Such inhibition may be determined readily by one of skill in the art according to standard assays (*e.g., Methods of Enzymology* 35: 155-160 (1975); and *Methods of Enzymology,* 110: 19-26 *(1985);* and the references cited therein). A variety of these compounds are described and referenced below. U.S. 5,120,729 discloses certain beta-lactam derivatives. U.S. 5,064,856 discloses certain spiro-lactone derivatives prepared by culturing the microorganism MF5253. U.S. 4,847,271 discloses certain oxetane compounds such as 11-(3-hydroxymethyl-4-oxo-2-oxetayl)-3,5,7-trimethyl-2,4-undecadienoic acid derivatives. Other HMG-CoA synthase inhibitors useful in the methods, compositions and kits of the present invention will be known to those skilled in the art.

Any compound that decreases HMG-CoA reductase gene expression may be used as an additional compound in the combination therapy aspect of this invention. These agents may be HMG-CoA reductase transcription inhibitors that block the transcription of DNA or translation inhibitors that prevent translation of mRNA coding for HMG-CoA reductase into protein. Such inhibitors may either affect transcription or translation

directly, or may be biotransformed into compounds that have the aforementioned attributes by one or more enzymes in the cholesterol biosynthetic cascade or may lead to the accumulation of an isoprene metabolite that has the aforementioned activities. Such regulation is readily determined by those skilled in the art according to standard assays (*Methods of Enzymology*, 110: 9-19 (1985)). Several such compounds are described and referenced below; however, other inhibitors of HMG-CoA reductase gene expression will be known to those skilled in the art, for example, U.S. 5,041,432 discloses certain 15-substituted lanosterol derivatives that are inhibitors of HMG-CoA reductase gene expression. Other oxygenated sterols that suppress the biosynthesis of HMG-CoA reductase are discussed by E. I. Mercer (*Prog. Lip. Res.*, 32:357-416 (1993)).

Any compound having activity as a CETP inhibitor can serve as the second compound in the combination therapy aspect of the instant invention. The term CETP inhibitor refers to compounds that inhibit the cholesteryl ester transfer protein (CETP) mediated transport of various cholesteryl esters and triglycerides from HDL to LDL and VLDL. A variety of these compounds are described and referenced below; however, other CETP inhibitors will be known to those skilled in the art. U.S. 5,512,548 discloses certain polypeptide derivatives having activity as CETP inhibitors, while certain CETP-inhibitory rosenonolactone derivatives and phosphate-containing analogs of cholesteryl ester are disclosed in *J. Antibiot.*, 49(8): 815-816 (1996), and *Bioorg. Med. Chem. Lett.*, 6:1951-1954 (1996), respectively.

Any ACAT inhibitor can serve as an additional compound in the combination therapy aspect of this invention. The term ACAT inhibitor refers to a compound that inhibits the intracellular esterification of dietary cholesterol by the enzyme acyl CoA: cholesterol acyltransferase. Such inhibition may be determined readily by one of skill in the art according to standard assays, such as the method of Heider *et al.* described in *Journal of Lipid Research*, 24:1127 (1983). A variety of these compounds are described and referenced below; however, other ACAT inhibitors will be known to those skilled in the art. U.S. 5,510,379 discloses certain carboxysulfonates, while WO 96/26948 and WO 96/10559 both disclose urea derivatives having ACAT inhibitory activity.

Any compound having activity as a squalene synthetase inhibitor can serve as an additional compound in the combination therapy aspect of the instant invention. The term squalene synthetase inhibitor refers to compounds that inhibit the condensation of two molecules of farnesylpyrophosphate to form squalene, a reaction that is catalyzed by the enzyme squalene synthetase. Such inhibition is readily determined by those skilled

in the art according to standard methodology *(Methods of Enzymology* 15:393-454 (1969); and *Methods of Enzymology* 110: 359-373 (1985); and references cited therein). A summary of squalene synthetase inhibitors has been complied in *Curr. Op. Ther Patents,* 861-4, (1993). EP 0 567 026 Al discloses certain 4,1-benzoxazepine derivatives as squalene synthetase inhibitors and their use in the treatment of hypercholesterolemia and as fungicides. EP 0 645 378 Al discloses certain seven- or eight-membered heterocycles as squalene synthetase inhibitors and their use in the treatment and prevention hypercholesterolemia and fungal infections. EP 0 645 377 Al discloses certain benzoxazepine derivatives as squalene synthetase inhibitors useful for the treatment of hypercholesterolemia or coronary sclerosis. EP 0 611 749 Al discloses certain substituted amic acid derivatives useful for the treatment of arteriosclerosis. EP 0 705 607 A2 discloses certain condensed seven- or eight-membered heterocyclic compounds useful as antihypertriglyceridemic agents. WO 96/09827 discloses certain combinations of cholesterol absorption inhibitors and cholesterol biosynthesis inhibitors including benzoxazepine derivatives and benzothiazepine derivatives. EP 0 701 725 Al discloses a process for preparing certain optically-active compounds, including benzoxazepine derivatives, having plasma cholesterol and triglyceride lowering activities.

Other compounds that are currently or previously marketed for hyperlipidemia, including hypercholesterolemia, and which are intended to help prevent or treat atherosclerosis, include bile acid sequestrants, such as colestipol HCl and cholestyramine; and fibric acid derivatives, such as clofibrate, fenofibrate, and gemfibrozil. These compounds can also be used in combination with a compound of the present invention.

It is also contemplated that the compounds of the present invention be administered with a lipase inhibitor and/or a glucosidase inhibitor, which are typically used in the treatment of conditions resulting from the presence of excess triglycerides, free fatty acids, cholesterol, cholesterol esters or glucose including, inter alia, obesity, hyperlipidemia, hyperlipoproteinemia, Syndrome X, and the like.

In a combination with a compound of the present invention, any lipase inhibitor or glucosidase inhibitor may be employed. In one aspect lipase inhibitors comprise gastric or pancreatic lipase inhibitors. In a further aspect glucosidase inhibitors comprise amylase inhibitors. Examples of glucosidase inhibitors are those inhibitors selected from the group consisting of acarbose, adiposine, voglibose, miglitol, emiglitate, camiglibose,

tendamistate, trestatin, pradimicin-Q and salbostatin. Examples of amylase inhibitors include tendamistat and the various cyclic peptides related thereto disclosed in U.S. Pat. No. 4,451,455, AI-3688 and the various cyclic polypeptides related thereto disclosed in U.S. Pat. No. 4,623,714, and trestatin, consisting of a mixture of trestatin A, trestatin B and trestatin C and the various trehalose-containing aminosugars related thereto disclosed in U.S. Pat. No. 4,273,765.

A lipase inhibitor is a compound that inhibits the metabolic cleavage of dietary triglycerides into free fatty acids and monoglycerides. Under normal physiological conditions, lipolysis occurs via a two-step process that involves acylation of an activated serine moiety of the lipase enzyme. This leads to the production of a fatty acid-lipase hemiacetal intermediate, which is then cleaved to release a diglyceride. Following further deacylation, the lipase-fatty acid intermediate is cleaved, resulting in free lipase, a monoglyceride and a fatty acid. The resultant free fatty acids and monoglycerides are incorporated into bile acid phospholipid micelles, which are subsequently absorbed at the level of the brush border of the small intestine. The micelles eventually enter the peripheral circulation as chylomicrons. Accordingly, compounds, including lipase inhibitors that selectively limit or inhibit the absorption of ingested fat precursors are useful in the treatment of conditions including obesity, hyperlipidemia, hyperlipoproteinemia, Syndrome X, and the like.

Pancreatic lipase mediates the metabolic cleavage of fatty acids from triglycerides at the 1- and 3-carbon positions. The primary site of the metabolism of ingested fats is in the duodenum and proximal jejunum by pancreatic lipase, which is usually secreted in vast excess of the amounts necessary for the breakdown of fats in the upper small intestine. Because pancreatic lipase is the primary enzyme required for the absorption of dietary triglycerides, inhibitors have utility in the treatment of obesity and the other related conditions.

Gastric lipase is an immunologically distinct lipase that is responsible for approximately 10 to 40% of the digestion of dietary fats. Gastric lipase is secreted in response to mechanical stimulation, ingestion of food, the presence of a fatty meal or by sympathetic agents. Gastric lipolysis of ingested fats is of physiological importance in the provision of fatty acids needed to trigger pancreatic lipase activity in the intestine and is also of importance for fat absorption in a variety of physiological and pathological conditions associated with pancreatic insufficiency. See, for example, C. K. Abrams, *et al.*, *Gastroenterology* 92: 125 (1987).

A variety of lipase inhibitors are known to one of ordinary skill in the art. However, in the practice of the methods, pharmaceutical compositions, and kits of the instant invention, generally lipase inhibitors are those inhibitors that are selected from the group consisting of lipstatin, tetrahydrolipstatin (orlistat), FL-386, WAY-121898, Bay-N-3176, valilactone, esterastin, ebelactone A, ebelactone B and RHC 80267.

The pancreatic lipase inhibitors lipstatin, 2S, 3S, *SS,* 7Z,1OZ)-5-[(S)-2-formamido-4-methyl-valeryloxy]-2-hexyl-3-hydroxy-7,1(t-hexadecan oic acid lactone, and tetrahydrolipostatin (orlistat), 2S, 3S, 55)-5-[(S)-2-formamido-4-methyl-valeryloxy]-2-hexyl-3-hydroxy-hexadecanoic acid lactone, and the variously substituted N-formylleucine derivatives and stereoisomers thereof, are disclosed in U.S. 4,598,089.

The pancreatic lipase inhibitor FL-386, 1-[4-(2-methylpropyl)cyclohexyl]-2-[(phenylsulfonyl)oxy]-ethanone, and the variously substituted sulfonate derivatives related thereto, are disclosed in U.S. 4,452,813.

The pancreatic lipase inhibitor WAY-121898, 4-phenoxyphenyl-4-methylpiperidin-1-yl-carboxylate, and the various carbamate esters and pharmaceutically acceptable salts related thereto, are disclosed in U.S. 5,512,565; 5,391,571 and 5,602,151.

The lipase inhibitor Bay-N-3176, N-3-trifiuoromethylphenyl-N'-3-chloro-4-trifiuorometbylphenylurea, and the various urea derivatives *65* related thereto, are disclosed in U.S. 4,405,644.

The pancreatic lipase inhibitor valilactone, and a process for the preparation thereof by the microbial cultivation of Aetinomycetes strain MG147—CF2, are disclosed in Kitahara, *et al., J. Antibiotics,* 40(11): 1647-50 (1987).

The lipase inhibitor esteracin, and certain processes for the preparation thereof by the microbial cultivation of Streptomyces strain ATCC 31336, are disclosed in U.S. 4,189,438 and 4,242,453.

The pancreatic lipase inhibitors ebelactone A and ebelactone B, and a process for the preparation thereof by the microbial cultivation of Actinomycetes strain MG7-G1, are disclosed in Umezawa, *et al., J. Antibiotics,* 33, 1594-1596 (1980). The use of ebelactones A and B in the suppression of monoglyceride formation is disclosed in Japanese Kokai 08-143457, published Jun. 4, 1996.

The lipase inhibitor RHC 80267, cyclo-O,O'-[(1,6-hexanediyl)-bis-(iminocarbonyl)]dioxime, and the various bis(iminocarbonyl)dioximes related thereto may be prepared as described in Petersen *et al., Liebig's Annalen,* 562: 205-29 (1949).

The ability of RHC 80267 to inhibit the activity of myocardial lipoprotein lipase is disclosed in Carroll *et al., Lipids,* 27 305-7 (1992) and Chuang *et al., J. Mol. Cell Cardiol.,* 22: 1009-16 (1990).

In another aspect of the present invention, the compounds of Formula I can be used in combination with an additional anti-obesity agent. The additional anti-obesity agent in one aspect is selected from the group consisting of a β_3-adrenergic receptor agonist, a cholecystokinin-A agonist, a monoamine reuptake inhibitor, a sympathomimetic agent, a serotoninergic agent, a dopamine agonist, a melanocyte-stimulating hormone receptor agonist or mimetic, a melanocyte-stimulating hormone receptor analog, a cannabinoid receptor antagonist, a melanin concentrating hormone antagonist, leptin, a leptin analog, a leptin receptor agonist, a galanin antagonist, a lipase inhibitor, a bombesin agonist, a neuropeptide-Y antagonist, a thyromimetic agent, dehydroepiandrosterone or an analog thereof, a glucocorticoid receptor agonist or antagonist, an orexin receptor antagonist, a urocortin binding protein antagonist, a glucagon-like peptide-1 receptor agonist, and a ciliary neurotrophic factor.

In an additional aspect the anti-obesity agents comprise those compounds selected from the group consisting of sibutramine, fenfluramine, dexfenfluramine, bromocriptine, phentermine, ephedrine, leptin, phenylpropanolamine pseudoephedrine, {4-[2-(2-[6-aminopyridin-3-yl]-2(R)-bydroxyethylamino)ethoxy]phenyl} acetic acid, {4{2-(2-[6-aminopyridin-3-yl]-2(R)-hydroxyethylamino)ethoxy]phenyl}benzoic acid, {4-[2-(2{6-aminopyridin-3-yl]-2(R)-hydroxyethylamino)ethoxy]phenyl}propionic acid, and {4-[2-(2-[6-aminopyridin-3-yl]-2(R)-hydroxyethylamino)ethoxy]phenoxy} acetic acid.

In one aspect, the present invention concerns the prevention or treatment of diabetes, including impaired glucose tolerance, insulin resistance, insulin dependent diabetes mellitus (Type I) and non-insulin dependent diabetes mellitus (NIDDM or Type II). Also included in the prevention or treatment of diabetes are the diabetic complications, such as neuropathy, nephropathy, retinopathy or cataracts.

In one aspect the type of diabetes to be treated by the compounds of the present invention is non-insulin dependent diabetes mellitus, also known as Type II diabetes or NIDDM.

Diabetes can be treated by administering to a patient having diabetes (Type I or Type II), insulin resistance, impaired glucose tolerance, or any of the diabetic complications such as neuropathy, nephropathy, retinopathy or cataracts, a therapeutically effective amount of a compound of the present invention. It is also contemplated that diabetes be treated by administering a compound of the present invention along with other agents that can be used to prevent or treat diabetes.

Representative agents that can be used to treat diabetes in combination with a compound of the present invention include insulin and insulin analogs (*e.g.*, LysPro insulin); GLP-1 (7-37) (insulinotropin) and GLP-1 (7-36) —NH_2. Agents that enhance insulin secretion, *e.g.*, eblorpropamide, glibenclamide, tolbutamide, tolazamide, acetohexamide, glypizide, glimepiride, repaglinide, nateglinide, meglitinide; biguanides: metformin, phenformin, buformin; A2-antagonists and imidazolines: midaglizole, isaglidole, deriglidole, idazoxan, efaroxan, fluparoxan; other insulin secretagogues linogliride, A-4166; glitazones: ciglitazone, pioglitazone, englitazone, troglitazone, darglitazone, BRL49653; fatty acid oxidation inhibitors: clomoxir, etomoxir; a-glucosidase inhibitors: acarbose, miglitol, emiglitate, voglibose, MDL25,637, camiglibose, MDL-73,945; ~3-agonists: BRL 35135, BRL 37344, RO 16-8714, ICI D7114, CL 316,243; phosphodiesterase inhibitors: -386,398; lipid-lowering agents benfluorex; antiobesity agents: fenfiuramine; vanadate and vanadium complexes (*e.g.*, bis(cysteinamide N-octyl) oxovanadium) and peroxovanadium complexes; amylin antagonists; glucagon antagonists; gluconeogenesis inhibitors; somatostatin analogs; antilipolytic agents: nicotinic acid, acipimox, WAG 994. Also contemplated to be used in combination with a compound of the present invention are pramlintide (symlinTM), AC 2993 and nateglinide. Any agent or combination of agents can be administered as described above.

In addition, the compounds of the present invention can be used in combination with one or more aldose reductase inhibitors, DPPIV inhibitor, glycogen phosphorylase inhibitors, sorbitol dehydrogenase inhibitors, NHE-1 inhibitors and/or glucocorticoid receptor antagonists.

Any compound having activity as a fructose -1,6-bisphosphatase (FBPase) inhibitor can serve as the second compound in the combination therapy aspect of the instant invention (*e.g.*, 2-Amino-5-isobutyl-4-{2-[5-(N,N'-bis((*S*)-1-ethoxycarbonyl)ethyl)phosphonamido]furanyl}thiazoles). FBPase is a key regulatory enzyme in gluconeogenesis, the metabolic pathway by which the liver synthesizes

glucose from 3-carbon precursors. The term FBPase inhibitor refers to compounds that inhibit FBPase enzyme activity and thereby block the conversion of fructose -1,6-bisphosphate, the substrate of the enzyme, to fructose 6-phosphate. FBPase inhibition can be determined directly at the enzyme level by those skilled in the art according to standard methodology (*e.g.*, Gidh-Jain M, Zhang Y, van Poelje PD *et al.*, *J Biol Chem.* 1994, 269(44): 27732-8). Alternatively, FBPase inhibition can be assessed according to standard methodology by measuring the inhibition of glucose production by isolated hepatocytes or in a perfused liver, or by measuring blood glucose lowering in normal or diabetic animals (*e.g.*, Vincent MF, Erion MD, Gruber HE, Van den Berghe, *Diabetologia.* 1996, 39(10):1148-55.; Vincent MF, Marangos PJ, Gruber HE, Van den Berghe G, *Diabetes* 1991 40(10):1259-66). In some cases, *in vivo* metabolic activation of a compound may be required to generate the FBPase inhibitor. This class of compounds may be inactive in the enzyme inhibition screen, may or may not be active in hepatocytes, but is active *in vivo* as evidenced by glucose lowering in the normal, fasted rat and/or in animal models of diabetes.

A variety of FBPase inhibitors are described and referenced below; however, other FBPase inhibitors will be known to those skilled in the art. Gruber *et al.* U.S. Patent No. 5,658,889 described the use of inhibitors of the AMP site of FBPase to treat diabetes; WO 98/39344 and US 6,284,748 describe purine inhibitors; WO 98/39343 and US 6,110,903 describe benzothiazole inhibitors to treat diabetes; WO 98/39342 and US 6,054,587 describe indole inhibitors to treat diabetes; and WO 00/14095 and US 6,489476 describe heteroaromatic phosphonate inhibitors to treat diabetes. Other FBPase inhibitors are described in Wright SW, Carlo AA, Carty MD *et al.*, *J Med Chem.* 2002 45(18):3865-77 and WO 99/47549.

The compounds of the present invention can also be used in combination with sulfonylureas such as amaryl, alyburide, glucotrol, chlorpropamide, diabinese, tolazamide, tolinase, acetohexamide, glipizide, tolbutamide, orinase, glimepiride, DiaBeta, micronase, glibenclamide, and gliclazide.

The compounds of the present invention can also be used in combination with antihypertensive agents. Any anti-hypertensive agent can be used as the second agent in such combinations. Examples of presently marketed products containing antihypertensive agents include calcium channel blockers, such as Cardizem, Adalat, Calan, Cardene, Covera, Dilacor, DynaCirc, Procardia XL, Sular, Tiazac, Vascor, Verelan, Isoptin, Nimotop, Norvasc, and Plendil; angiotensin converting enzyme (ACE)

inhibitors, such as Accupril, Altace, Captopril, Lotensin, Mavik, Monopril, Prinivil, Univasc, Vasotec and Zestril.

Examples of compounds that may be used in combination with the compounds of the present invention to prevent or treat osteoporosis include: anti-resorptive agents including progestins, polyphosphonates, bisphosphonate(s), estrogen agonists/antagonists, estrogen, estrogen/progestin combinations, Premarin, estrone, estriol or 17.alpha.- or 17.beta.-ethynyl estradiol); progestins including algestone acetophenide, altrenogest, amadinone acetate, anagestone acetate, chlormadinone acetate, cingestol, clogestone acetate, clomegestone acetate, delmadinone acetate, desogestrel, dimethisterone, dydrogesterone, ethynerone, ethynodiol diacetate, etonogestrel, flurogestone acetate, gestaclone, gestodene, gestonorone caproate, gestrinone, haloprogesterone, hydroxyprogesterone caproate, levonorgestrel, lynestrenol, medrogestone, medroxyprogesterone acetate, melengestrol acetate, methynodiol diacetate, norethindrone, norethindrone acetate, norethynodrel, norgestimate, norgestomet, norgestrel, oxogestone phenpropionate, progesterone, quingestanol acetate, quingestrone, and tigestol; and bone resorption inhibiting polyphosphonates including polyphosphonates such as of the type disclosed in U.S. Pat. No. 3,683,080, the disclosure of which is incorporated herein by reference. Examples of polyphosphonates include geminal diphosphonates (also referred to as bis-phosphonates), tiludronate disodium, ibandronic acid, alendronate, resindronate zoledronic acid, 6-amino-1-hydroxy-hexylidene-bisphosphonic acid and 1-hydroxy-3(methylpentylamino)-propylidene-bisphosphonic acid. Salts, co-crystals and esters of the polyphosphonates are likewise included. Specific examples include ethane-1-hydroxy 1,1-diphosphonic acid, methane diphosphonic acid, pentane-1-hydroxy-1,1-diphosphonic acid, methane dichloro diphosphonic acid, methane hydroxy diphosphonic acid, ethane-1-amino-1,1-diphosphonic acid, ethane-2-amino-1,1-diphosphonic acid, propane-3-amino-1-hydroxy-1,1-diphosphonic acid, propane-N,N-dimethyl-3-amino-1-hydroxy-1,1-diphosphonic acid, propane-3,3-dimethyl-3-amino-1-hydroxy-1,1-diphosphonic acid, phenyl amino methane diphosphonic acid, N,N-dimethylamino methane diphosphonic acid, N(2-hydroxyethyl) amino methane diphosphonic acid, butane-4-amino-1-hydroxy-1,1-diphosphonic acid, pentane-5-amino-1-hydroxy- -1,1-diphosphonic acid, and hexane-6-amino-1-hydroxy-1,1-diphosphonic acid.

Estrogen agonist/antagonist include 3-(4-(1,2-diphenyl-but-1-enyl)-phenyl)-acrylic acidr, tamoxifen: (ethanamine, 2-(-4-(1,2-diphenyl-1-butenyl)phenoxy)-N,N-

dimethyl, (Z)-2-, 2-hydroxy-1,2,3-propanetricarboxylate(1:1)) and related compounds which are disclosed in U.S. Pat. No. 4,536,516, the disclosure of which is incorporated herein by reference, 4-hydroxy tamoxifen, which is disclosed in U.S. Pat. No. 4,623,660, the disclosure of which is incorporated herein by reference, raloxifene: (methanone, (6-hydroxy-2-(4-hydroxyphenyl)benzo[b]thien-3-yl)(4-(2-(1-piperidinyl)eth- oxy)phenyl)-hydrochloride) which is disclosed in U.S. Pat. No. 4,418,068, the disclosure of which is incorporated herein by reference, toremifene: (ethanamine, 2-(4-(4-chloro-1,2-diphenyl-1-butenyl)phenoxy)-N,N-dimethyl-- , (Z)-, 2-hydroxy-1,2,3-propanetricarboxylate (1:1) which is disclosed in U.S. Pat. No. 4,996,225, the disclosure of which is incorporated herein by reference, centchroman: 1-(2-((4-(-methoxy-2,2, dimethyl-3-phenyl-chroman-4-yl)-phenoxy)-ethyl)-p- yrrolidine, which is disclosed in U.S. Pat. No. 3,822,287, the disclosure of which is incorporated herein by reference, levormeloxifene, idoxifene: (E)-1-(2-(4-(1-(4-iodo-phenyl)-2-phenyl-but-1-enyl)-phenoxy)-ethyl)-pyrro- lidinone, which is disclosed in U.S. Pat. No. 4,839,155, the disclosure of which is incorporated herein by reference, 2-(4-methoxy-phenyl)-3-[4-(2-piperidin-1-yl-ethoxy)-phenoxy]-benzo[b]thiophen-6-ol which is disclosed in U.S. Pat. No. 5,488,058, the disclosure of which is incorporated herein by reference, 6-(4-hydroxy-phenyl)-5-(4-(2-piperidin-1-yl-ethoxy)-benzyl)-naphthalen-2-- ol, which is disclosed in U.S. Pat. No. 5,484,795, the disclosure of which is incorporated herein by reference, (4-(2-(2-aza-bicyclo[2.2.1]hept-2-yl)-ethoxy)-phenyl)-(6-hydroxy-2-(4-hyd- roxy-phenyl)-benzo[b]thiophen-3-yl)-methanone which is disclosed, along with methods of preparation, in PCT publication no. WO 95/10513 assigned to Pfizer Inc, TSE-424 (Wyeth-Ayerst Laboratories) and arazoxifene, cis-6-(4-fluoro-phenyl)-5-(4-(2-piperidin-1-yl-ethoxy)-phenyl)-5,6,- 7,8-tetrahydro-naphthalene-2-ol; (-)-cis-6-phenyl-5-(4-(2-pyrrolidin-1-yl-ethoxy)-phenyl)-5,6,7,8-tetrahydro-naphthalene-2-ol (also known as lasofoxifene); cis-6-phenyl-5-(4-(2-pyrrolidin-1-yl-ethoxy)-phenyl)-5,6,7,8-tetrah- ydro-naphthalene-2-ol; cis-1-(6'-pyrrolodinoethoxy-3'-pyridyl)-2-phenyl-6-hydroxy-1,2,3,4-- tetrahydronaphthalene; 1-(4'-pyrrolidinoethoxyphenyl)-2-(4"-fluorophenyl)-6-hydroxy-1,2,3,- 4-tetrahydroisoquinoline; cis-6-(4-hydroxyphenyl)-5-(4-(2-piperidin-1-yl-ethoxy)-phenyl)-5,6,- 7,8-tetrahydro-naphthalene-2-ol; 1-(4'-pyrrolidinolethoxyphenyl)-2-phenyl-6-hydroxy-1,2,3,4-tetrahyd- roisoquinoline, 2-phenyl-3-aroyl-benzoth- iophene and 2-phenyl-3-aroylbenzothiophene-1-oxide.

Other anti-osteoporosis agents, which can be used as the second agent in combination with a compound of the present invention, include, for example, the

following: parathyroid hormone (PTH) (a bone anabolic agent); parathyroid hormone (PTH) secretagogues (see, e.g., U.S. Pat. No. 6,132,774), particularly calcium receptor antagonists; calcitonin; and vitamin D and vitamin D analogs. Further anti-osteoporosis agents includes a selective androgen receptor modulator (SARM). Examples of suitable SARMs include compounds such as cyproterone acetate, chlormadinone, flutamide, hydroxyflutamide, bicalutamide, nilutamide, spironolactone, 4-(trifluoromethyl)-2(1H)-pyrrolidino[3,2-g] quinoline derivatives, 1,2-dihydropyridino[5,6-g]quinoline derivatives and piperidino[3,2-g]quinolinone derivatives. Other examples include cypterone, also known as (1b,2b)-6-chloro-1,2-dihydro-17-hydroxy-3'- H-cyclopropa[1,2]pregna-1,4,6-triene-3,20-dione is disclosed in U.S. Pat. No. 3,234,093. Chlormadinone, also known as 17-(acetyloxy)-6-chloropregna- -4,6-diene-3,20-dione, in its acetate form, acts as an anti-androgen and is disclosed in U.S. Pat. No. 3,485,852. Nilutamide, also known as 5,5-dimethyl-3-[4-nito-3-(trifluoromethyl)phenyl]-2,4-imidazolidinedione and by the trade name Nilandron.RTM. is disclosed in U.S. Pat. No. 4,097,578. Flutamide, also known as 2-methyl-N-[4-nitro-3-(trifluoromethy- l)phenyl]propanamide and the trade name Eulexin.RTM. is disclosed in U.S. Pat. No. 3,847,988. Bicalutamide, also known as 4'-cyano-a',a',a'-trifluo- ro-3-(4-fluorophenylsulfonyl)-2-hydroxy-2-methylpropiono-m-toluidide and the trade name Casodex.RTM. is disclosed in EP-100172. The enantiomers of biclutamide are discussed by Tucker and Chesterton, J. Med. Chem. 1988, 31, 885-887. Hydroxyflutamide, a known androgen receptor antagonist in most tissues, has been suggested to function as a SARM for effects on IL-6 production by osteoblasts as disclosed in Hofbauer et al. J. Bone Miner. Res. 1999, 14, 1330-1337. Additional SARMs have been disclosed in U.S. Pat. No. 6,017,924; WO 01/16108, WO 01/16133, WO 01/16139, WO 02/00617, WO 02/16310, U.S. Patent Application Publication No. US 2002/0099096, U.S. Patent Application Publication No. US 2003/0022868, WO 03/011302 and WO 03/011824. All of the above references are hereby incorporated by reference herein.

Formulations

Unit dose amounts and dose scheduleing for the pharmaceutical compositions of the present invention can be determined using methods well known in the art. In one aspect, the compounds of the invention are administered orally in a total daily dose of about 0.375 μg/kg/day to about 3.75 mg/kg/day. In another aspect the total daily dose is from about 3.75 μg/kg/day to about 0.375 mg/kg/day. In another aspect the total daily dose is from about 3.75 μg/kg/day to about 37.5 μg/kg/day. In another aspect the total

daily dose is from about 3.75 μg/kg/day to about 60 μg/kg/day. In a further aspect the dose range is from 30 μg/kg/day to 3.0 mg/kg/day. In one aspect, the compounds of the invention are administered orally in a unit dose of about 0.375 μg/kg to about 3.75 mg/kg. In another aspect the unit dose is from about 3.75 μg/kg to about 0.375 mg/kg. In another aspect the unit dose is from about 3.75 μg/kg to about 37.5 μg/kg. In another aspect the unit dose is from about 3.75 μg/kg to about 60 μg/kg. In one aspect, the compounds of the invention are administered orally in a unit dose of about 0.188 μg/kg to about 1.88 mg/kg. In another aspect the unit dose is from about 1.88 μg/kg to about 0.188 mg/kg. In another aspect the unit dose is from about 1.88 μg/kg to about 18.8 μg/kg. In another aspect the unit dose is from about 1.88 μg/kg to about 30 μg/kg. In one aspect, the compounds of the invention are administered orally in a unit dose of about 0.125 μg/kg to about 1.25 mg/kg. In another aspect the unit dose is from about 1.25 μg/kg to about 0.125 mg/kg. In another aspect the unit dose is from about 1.25 μg/kg to about 12.5 μg/kg. In another aspect the unit dose is from about 1.25 μg/kg to about 20 μg/kg. In one embodiment the unit dose is administered once a day. In another embodiment the unit dose is administered twice a day. In another embodiment the unit dose is administered three times a day. In another embodiment the unit dose is administered four times a day.

Dose refers to the equivalent of the free acid. The use of controlled-release preparations to control the rate of release of the active ingredient may be preferred. The daily dose may be administered in multiple divided doses over the period of a day. Doses and dosing schedules may be adjusted to the form of the drug or form of delivery used. For example, different dosages and scheduling of doses may be used when the form of the drug is in a controlled release form or intravenous delivery is used with a liquid form.

Compounds of this invention when used in combination with other compounds or agents may be administered as a daily dose or an appropriate fraction of the daily dose (*e.g.*, bid). Administration of compounds of this invention may occur at or near the time in which the other compound or agent is administered or at a different time. When compounds of this invention are used in combination with other compounds or agents, the other compound or agent (*e.g.*, atorvastatin) may be administered at the approved dose or a lower dose.

For the purposes of this invention, the compounds may be administered by a variety of means including orally, parenterally, by inhalation including but not limited to

nasal spray, topically, implantables or rectally in formulations containing pharmaceutically acceptable carriers, adjuvants and vehicles. The term parenteral as used here includes subcutaneous, intravenous, intramuscular, and intra-arterial injections with a variety of infusion techniques. Intra-arterial and intravenous injection as used herein includes administration through catheters. Oral administration is generally preferred.

Pharmaceutical compositions containing the active ingredient may be in any form suitable for the intended method of administration. When used for oral use for example, tablets, pellets, troches, lozenges, aqueous or oil suspensions, dispersible powders or granules, emulsions, hard or soft capsules, syrups or elixirs may be prepared. Compositions intended for oral use may be prepared according to any method known to the art for the manufacture of pharmaceutical compositions and such compositions may contain one or more agents including sweetening agents, flavoring agents, coloring agents and preserving agents, in order to provide a palatable preparation. Tablets and pellets containing the active ingredient in admixture with non-toxic pharmaceutically acceptable excipient which are suitable for manufacture of tablets are acceptable. These excipients may be, for example, inert diluents, such as calcium or sodium carbonate, lactose, calcium or sodium phosphate; granulating and disintegrating agents, such as maize starch, or alginic acid; binding agents, such as starch, gelatin or acacia; and lubricating agents, such as magnesium stearate, stearic acid or talc. Tablets and pellets may be uncoated or may be coated by known techniques including microencapsulation to delay disintegration and adsorption in the gastrointestinal tract and thereby provide a sustained action over a longer period. For example, a time delay material such as glyceryl monostearate or glyceryl distearate alone or with a wax may be employed.

Formulations for oral use may be also presented as hard gelatin capsules where the active ingredient is mixed with an inert solid diluent, for example calcium phosphate or kaolin, or as soft gelatin capsules wherein the active ingredient is mixed with water or an oil medium, such as peanut oil, liquid paraffin or olive oil.

Aqueous suspensions of the invention contain the active materials in admixture with excipients suitable for the manufacture of aqueous suspensions. Such excipients include a suspending agent, such as sodium carboxymethylcellulose, methylcellulose, hydroxypropyl methylcelluose, sodium alginate, polyvinylpyrrolidone, gum tragacanth and gum acacia, and dispersing or wetting agents such as a naturally occurring phosphatide (*e.g.*, lecithin), a condensation product of an alkylene oxide with a fatty acid

(*e.g.*, polyoxyethylene stearate), a condensation product of ethylene oxide with a long chain aliphatic alcohol (*e.g.*, heptadecaethyleneoxycetanol), a condensation product of ethylene oxide with a partial ester derived from a fatty acid and a hexitol anhydride (*e.g.*, polyoxyethylene sorbitan monooleate). The aqueous suspension may also contain one or more preservatives such as ethyl or n-propyl p-hydroxy-benzoate, one or more coloring agents, one or more flavoring agents and one or more sweetening agents, such as sucrose or saccharin.

Oil suspensions may be formulated by suspending the active ingredient in a vegetable oil, such as arachis oil, olive oil, sesame oil or coconut oil, or in a mineral oil such as liquid paraffin. The oral suspensions may contain a thickening agent, such as beeswax, hard paraffin or cetyl alcohol. Sweetening agents, such as those set forth above, and flavoring agents may be added to provide a palatable oral preparation. These compositions may be preserved by the addition of an antioxidant such as ascorbic acid.

Dispersible powders, pellets, and granules of the invention suitable for preparation of an aqueous suspension by the addition of water provide the active ingredient in admixture with a dispersing or wetting agent, a suspending agent, and one or more preservatives. Suitable dispersing or wetting agents and suspending agents are exemplified by those disclosed above. Additional excipients, for example sweetening, flavoring and coloring agents, may also be present.

The pharmaceutical compositions may also be in the form of oil-in-water emulsions. The oily phase may be a vegetable oil, such as olive oil or arachis oil, a mineral oil, such as liquid paraffin, or a mixture of these. Suitable emulsifying agents include naturally-occurring gums, such as gum acacia and gum tragacanth, naturally occurring phosphatides, such as soybean lecithin, esters or partial esters derived from fatty acids and hexitol anhydrides, such as sorbitan monooleate, and condensation products of these partial esters with ethylene oxide, such as polyoxyethylene sorbitan monooleate. The emulsion may also contain sweetening and flavoring agents.

Syrups and elixirs may be formulated with sweetening agents, such as glycerol, sorbitol or sucrose. Such formulations may also contain a demulcent, a preservative, a flavoring or a coloring agent.

In another aspect the pharmaceutical compositions may be in the form of a sterile injectable preparation, such as a sterile injectable aqueous or oleaginous suspension. This suspension may be formulated according to the known art using those suitable dispersing or wetting agents and suspending agents which have been mentioned above.

The sterile injectable preparation may also be a sterile injectable solution or suspension in a non-toxic parenterally acceptable diluent or solvent, such as a solution in 1,3-butane-diol or prepared as a lyophilized powder. Among the acceptable vehicles and solvents that may be employed are water, Ringer's solution and isotonic sodium chloride solution. In addition, sterile fixed oils may conventionally be employed as a solvent or suspending medium. For this purpose any bland fixed oil may be employed including synthetic mono- or diglycerides. In addition, fatty acids such as oleic acid may likewise be used in the preparation of injectables.

The amount of active ingredient that may be combined with the carrier material to produce a single dosage form will vary depending upon the host treated and the particular mode of administration. For example, a time-release formulation intended for oral administration to humans may contain 0.2 to 2000 μmol (approximately 0.1 to 1000 mg) of active material compounded with an appropriate and convenient amount of carrier material which may vary from about 5 to about 99.9% of the total compositions. It is preferred that the pharmaceutical composition be prepared which provides easily measurable amounts for administration. For example, an aqueous solution intended for intravenous infusion should contain from about 0.05 to about 500 μmol (approximately 0.025 to 250 mg) of the active ingredient per milliliter of solution in order that infusion of a suitable volume at a rate of about 30 mL/h can occur.

As noted above, formulations suitable for oral administration may be presented as discrete units such as capsules, cachets, pellets, or tablets each containing a predetermined amount of the active ingredient; as a powder or granules; as a solution or a suspension in an aqueous or non-aqueous liquid; or as an oil-in-water liquid emulsion or a water-in-oil liquid emulsion. The active ingredient may also be administered as a bolus, electuary or paste.

A tablet may be made by compression or molding, optionally with one or more accessory ingredients. Compressed tablets may be prepared by compressing in a suitable machine the active ingredient in a free flowing form such as a powder or granules, optionally mixed with a binder (*e.g.*, povidone, gelatin, hydroxypropylmethyl cellulose), lubricant, inert diluent, preservative, disintegrant (*e.g.*, sodium starch glycolate, cross-linked povidone, cross-linked sodium carboxymethyl cellulose) surface active or dispersing agent. Molded tablets may be made by molding in a suitable machine a mixture of the powdered compound moistened with an inert liquid diluent. Tablets may optionally be provided with an enteric coating, to provide release in parts of the gut other

than the stomach. This is particularly advantageous with the compounds of of the present invention when such compounds are susceptible to acid hydrolysis.

Pharmaceutical compositions comprising the compounds of the present invention can be administered by controlled- or delayed-release means. Controlled-release pharmaceutical products have a common goal of improving drug therapy over that achieved by their non-controlled release counterparts. Ideally, the use of an optimally designed controlled-release preparation in medical treatment is characterized by a minimum of drug substance being employed to treat or control the condition in a minimum amount of time. Advantages of controlled-release formulations include: 1) extended activity of the drug; 2) reduced dosage frequency; 3) increased patient compliance; 4) usage of less total drug; 5) reduction in local or systemic side effects; 6) minimization of drug accumulation; 7) reduction in blood level fluctuations; 8) improvement in efficacy of treatment; 9) reduction of potentiation or loss of drug activity; and 10) improvement in speed of control of diseases or conditions. (Kim, Cherng-ju, Controlled Release Dosage Form Design, 2 Technomic Publishing, Lancaster, Pa.: 2000).

Conventional dosage forms generally provide rapid or immediate drug release from the formulation. Depending on the pharmacology and pharmacokinetics of the drug, use of conventional dosage forms can lead to wide fluctuations in the concentrations of the drug in a patient's blood and other tissues. These fluctuations can impact a number of parameters, such as dose frequency, onset of action, duration of efficacy, maintenance of therapeutic blood levels, toxicity, side effects, and the like. Advantageously, controlled-release formulations can be used to control a drug's onset of action, duration of action, plasma levels within the therapeutic window, and peak blood levels. In particular, controlled- or extended-release dosage forms or formulations can be used to ensure that the maximum effectiveness of a drug is achieved while minimizing potential adverse effects and safety concerns, which can occur both from under dosing a drug (i.e., going below the minimum therapeutic levels) as well as exceeding the toxicity level for the drug.

Most controlled-release formulations are designed to initially release an amount of drug (active ingredient) that promptly produces the desired therapeutic effect, and gradually and continually release other amounts of drug to maintain this level of therapeutic or prophylactic effect over an extended period of time. In order to maintain this constant level of drug in the body, the drug must be released from the dosage form at

a rate that will replace the amount of drug being metabolized and excreted from the body. Controlled-release of an active ingredient can be stimulated by various conditions including, but not limited to, pH, ionic strength, osmotic pressure, temperature, enzymes, water, and other physiological conditions or compounds.

A variety of known controlled- or extended-release dosage forms, formulations, and devices can be adapted for use with the compositions of the invention. Examples include, but are not limited to, those described in U.S. Pat. Nos. 3,845,770; 3,916,899; 3,536,809; 3,598,123; 4,008,719; 5,674,533; 5,059,595; 5,591,767; 5,120,548; 5,073,543; 5,639,476; 5,354,556; 5,733,566; and 6,365,185 B1; each of which is incorporated herein by reference. These dosage forms can be used to provide slow or controlled-release of one or more active ingredients using, for example, hydroxypropylmethyl cellulose, other polymer matrices, gels, permeable membranes, osmotic systems (such as OROS.RTM. (Alza Corporation, Mountain View, Calif. USA)), multilayer coatings, microparticles, liposomes, or microspheres or a combination thereof to provide the desired release profile in varying proportions. Additionally, ion exchange materials can be used to prepare immobilized forms of compositions of the invention and thus effect controlled delivery of the drug. Examples of specific anion exchangers include, but are not limited to, DUOLITE A568 and DUOLITE AP143 (Rohm & Haas, Spring House, Pa. USA).

One embodiment of the invention encompasses a unit dosage form which comprises a compound of the present invention or a pharmaceutically acceptable salt, or a polymorph, solvate, hydrate, dehydrate, co-crystal, anhydrous, or amorphous form thereof, and one or more pharmaceutically acceptable excipients or diluents, wherein the pharmaceutical composition or dosage form is formulated for controlled-release. Specific dosage forms utilize an osmotic drug delivery system.

A particular and well-known osmotic drug delivery system is referred to as OROS (Alza Corporation, Mountain View, Calif. USA). This technology can readily be adapted for the delivery of compounds and compositions of the invention. Various aspects of the technology are disclosed in U.S. Pat. Nos. 6,375,978 B1; 6,368,626 B 1; 6,342,249 B1; 6,333,050 B2; 6,287,295 B1; 6,283,953 B1; 6,270,787 B1; 6,245,357 B1; and 6,132,420; each of which is incorporated herein by reference. Specific adaptations of OROS that can be used to administer compounds and compositions of the invention include, but are not limited to, the OROS Push-Pull, Delayed Push-Pull, Multi-Layer Push-Pull, and Push-Stick Systems, all of which are well known. Additional OROS

systems that can be used for the controlled oral delivery of compounds and compositions of the invention include OROS-CT and L-OROS. Id.; see also, Delivery Times, vol. II, issue II (Alza Corporation).

Conventional OROS oral dosage forms are made by compressing a drug powder (e.g., a T3 mimetic composition of the present invention) into a hard tablet, coating the tablet with cellulose derivatives to form a semi-permeable membrane, and then drilling an orifice in the coating (e.g., with a laser). (Kim, Cherng-ju, Controlled Release Dosage Form Design, 231-238 Technomic Publishing, Lancaster, Pa. 2000). The advantage of such dosage forms is that the delivery rate of the drug is not influenced by physiological or experimental conditions. Even a drug with a pH-dependent solubility can be delivered at a constant rate regardless of the pH of the delivery medium. But because these advantages are provided by a build-up of osmotic pressure within the dosage form after administration, conventional OROS drug delivery systems cannot be used to effectively deliver drugs with low water solubility.

A specific dosage form of the invention comprises: a wall defining a cavity, the wall having an exit orifice formed or formable therein and at least a portion of the wall being semipermeable; an expandable layer located within the cavity remote from the exit orifice and in fluid communication with the semipermeable portion of the wall; a dry or substantially dry state drug layer located within the cavity adjacent to the exit orifice and in direct or indirect contacting relationship with the expandable layer; and a flow-promoting layer interposed between the inner surface of the wall and at least the external surface of the drug layer located within the cavity, wherein the drug layer comprises a compound of the present invention, including a polymorph, solvate, hydrate, dehydrate, co-crystal, anhydrous, or amorphous form thereof. See U.S. Pat. No. 6,368,626, the entirety of which is incorporated herein by reference.

Another specific dosage form of the invention comprises: a wall defining a cavity, the wall having an exit orifice formed or formable therein and at least a portion of the wall being semipermeable; an expandable layer located within the cavity remote from the exit orifice and in fluid communication with the semipermeable portion of the wall; a drug layer located within the cavity adjacent the exit orifice and in direct or indirect contacting relationship with the expandable layer; the drug layer comprising a liquid, active agent formulation absorbed in porous particles, the porous particles being adapted to resist compaction forces sufficient to form a compacted drug layer without significant exudation of the liquid, active agent formulation, the dosage form optionally having a

placebo layer between the exit orifice and the drug layer, wherein the active agent formulation comprises a compound of the present invention, including a polymorph, solvate, hydrate, dehydrate, co-crystal, anhydrous, or amorphous form thereof. See U.S. Pat. No. 6,342,249, the entirety of which is incorporated herein by reference.

Transdermal Delivery System: The controlled release formulations of the present invention may be formulated as a transdermal delivery system, such as transdermal patches. In certain embodiments of the present invention, a transdermal patch comprises a compound of the present invention contained in a reservoir or a matrix, and an adhesive which allows the transdermal device to adhere to the skin, allowing the passage of the active agent from the transdermal device through the skin of the patient. Once the compound has penetrated the skin layer, the drug is absorbed into the blood stream where it exerts desired pharmaceutical effects. The transdermal patch releases the compound of the present invention in a controlled-release manner, such that the blood levels of the a compound of the present invention is maintained at a therapeutically effective level through out the dosing period, and the blood levels of the a compound of the present invention is maintained at a concentration that is sufficient to reduce side effects associated with immediate release dosage forms but not sufficient to negate the therapeutic effectiveness of the compound.

Transdermal refers to the delivery of a compound by passage through the skin or mucosal tissue and into the blood stream. There are four main types of transdermal patches listed below.

1. Single-layer Drug-in-Adhesive: The adhesive layer of this system also contains the drug. In this type of patch the adhesive layer not only serves to adhere the various layers together, along with the entire system to the skin, but is also responsible for the releasing of the drug. The adhesive layer is surrounded by a temporary liner and a backing.
2. Multi-layer Drug-in-Adhesive: The multi-layer drug-in adhesive patch is similar to the single-layer system in that both adhesive layers are also responsible for the releasing of the drug. The multi-layer system is different however that it adds another layer of drug-in-adhesive, usually separated by a membrane (but not in all cases). This patch also has a temporary liner-layer and a permanent backing.
3. Reservoir: Unlike the Single-layer and Multi-layer Drug-in-adhesive systems the resevoir transdermal system has a separate drug layer. The drug layer is a liquid

compartment containing a drug solution or suspension separated by the adhesive layer. This patch is also backed by the backing layer.

4. Matrix: The Matrix system has a drug layer of a semisolid matrix containing a drug solution or suspension. The adhesive layer in this patch surrounds the drug layer partially overlaying it.

Other modes of transdermal delivery are known in the art and are included in the present invention.

Formulations suitable for topical administration in the mouth include lozenges comprising the active ingredient in a flavored base, usually sucrose and acacia or tragacanth; pastilles comprising the active ingredient in an inert base such as gelatin and glycerin, or sucrose and acacia; and mouthwashes comprising the active ingredient in a suitable liquid carrier.

Formulations for rectal administration may be presented as a suppository with a suitable base comprising for example cocoa butter or a salicylate.

Formulations suitable for vaginal administration may be presented as pessaries, tampons, creams, gels, pastes, foams or spray formulations containing in addition to the active ingredient such carriers as are known in the art to be appropriate.

Formulations suitable for parenteral administration include aqueous and non-aqueous isotonic sterile injection solutions which may contain antioxidants, buffers, bacteriostats and solutes which render the formulation isotonic with the blood of the intended recipient; and aqueous and non-aqueous sterile suspensions which may include suspending agents and thickening agents. The formulations may be presented in unit-dose or multi-dose sealed containers, for example, ampoules and vials, and may be stored in a freeze-dried (lyophilized) condition requiring only the addition of the sterile liquid carrier, for example water for injections, immediately prior to use. Injection solutions and suspensions may be prepared from sterile powders, granules and tablets of the kind previously described.

In one aspect the unit dosage formulations are those containing a daily dose or unit, daily sub-dose, or an appropriate fraction thereof, of a drug.

It will be understood, however, that the specific dose level for any particular patient will depend on a variety of factors including the activity of the specific compound employed; the age, body weight, general health, sex and diet of the individual being treated; the time and route of administration; the rate of excretion; other drugs

which have previously been administered; and the severity of the particular disease undergoing therapy, as is well understood by those skilled in the art.

SYNTHESIS OF COMPOUNDS OF FORMULA I

The compounds in this invention may be prepared by the processes described in the following Schemes, as well as relevant published literature procedures that are used by those skilled in the art. It should be understood that the following schemes are provided solely for the purpose of illustration and do not limit the invention which is defined by the claims. Typically the synthesis of a compound of Formula I includes the following general steps: (1) Preparation of a phosphonate prodrug; (2) Deprotection of a phosphonate ester; (3) Introduction of a phosphonate group; (4) Construction of the diaryl ring system; and (5) Preparation of key precursors. The order of introduction of a phosphonate group and the construction of the diaryl backbone in the synthesis of compounds of Formula I can be freely decided by those skilled in the art based on the structure of the substrate. In all applicable structures contained in the Schemes described in this invention, PG refers to a protecting group and FG refers to a functional group that can be transformed into T. Protection and deprotection in the Schemes may be carried out according to the procedures generally known in the art (*e.g.*, "Protecting Groups in Organic Synthesis", 3rd Edition, Wiley, 1999).

All stereoisomers of the compounds of the instant invention are contemplated, either in admixture or in pure or substantially pure form. The compounds of the present invention can have stereogenic centers at the phosphorus atom and at any of the carbons including any of the R substituents. Consequently, compounds of Formula I can exist in enantiomeric or diastereomeric forms or in mixture thereof. The processes for preparation can utilize racemates, enantiomers or diastereomers as starting materials. When enantiomeric or diastereomeric products are prepared, they can be separated by conventional methods for example, chromatographic or fractional crystallization.

Preparation of A Phosphonate Prodrug

Prodrugs can be introduced at different stages of the synthesis. Most often these prodrugs are made from the phosphonic acids of Formula I because of their lability.

Phosphonic acids of Formula I can be alkylated with electrophiles such as alkyl halides and alkyl sulfonates under nucleophilic substitution conditions to give phosphonate esters. For example, compounds of Formula I wherein YR^{11} is an

acyloxyalkyl group can be prepared by direct alkylation of compounds of Formula I with an appropriate acyloxyalkyl halide (*e.g.*, Cl, Br, I; *Phosphorus Sulfur* **1990**, *54*, 143; *Synthesis* **1988**, 62) in the presence of a suitable base (*e.g.*, pyridine, TEA, diisopropylethylamine) in suitable solvents such as DMF (*J. Med. Chem.* **1994**, *37*, 1875). The carboxylate component of these acyloxyalkyl halides includes but is not limited to acetate, propionate, isobutyrate, pivalate, benzoate, carbonate and other carboxylates.

Dimethylformamide dialkyl acetals can also be used for the alkylation of phosphonic acids (*Collect. Czech Chem. Commu.* **1994**, *59*, 1853). Compounds of Formula I wherein YR^{11} is a cyclic carbonate, a lactone or a phthalidyl group can also be synthesized by direct alkylation of the free phosphonic acids with appropriate halides in the presence of a suitable base such as NaH or diisopropylethylamine (*J. Med. Chem.* **1995**, *38*, 1372; *J. Med. Chem.* **1994**, *37*, 1857; *J. Pharm. Sci.* **1987**, *76*, 180).

Alternatively, these phosphonate prodrugs can be synthesized by the reactions of the corresponding dichlorophosphonates and an alcohol (*Collect Czech Chem. Commun.* **1994**, *59*, 1853). For example, a dichlorophosphonate is reacted with substituted phenols and arylalkyl alcohols in the presence of a base such as pyridine or TEA to give the compounds of Formula I wherein YR^{11} is an aryl group (*J. Med. Chem.* **1996**, *39*, 4109; *J. Med. Chem.* **1995**, *38*, 1372; *J. Med. Chem.* **1994**, *37*, 498) or an arylalkyl group (*J. Chem. Soc. Perkin Trans. 1* **1992**, *38*, 2345). The disulfide-containing prodrugs (*Antiviral Res.* **1993**, *22*, 155) can be prepared from a dichlorophosphonate and 2-hydroxyethyldisulfide under standard conditions. Dichlorophosphonates are also useful for the preparation of various phosphonamides as prodrugs. For example, treatment of a dichlorophosphonate with ammonia gives both a monophosphonamide and a diphosphonamide; treatment of a dichlorophosphonate with 1-amino-3-propanol gives a cyclic 1,3-propylphosphonamide; treatment of a chlorophosphonate monophenyl ester with an aminoacid ester in the presence of a suitable base gives a substituted monophenyl monophosphonamidate.

Such reactive dichlorophosphonates can be generated from the corresponding phosphonic acids with a chlorinating agent (*e.g.*, thionyl chloride, *J. Med. Chem.* **1994**, 1857; oxalyl chloride, *Tetrahedron Lett.* **1990**, *31*, 3261; phosphorous pentachloride, *Synthesis* **1974**, 490). Alternatively, a dichlorophosphonate can be generated from its corresponding disilyl phosphonate esters (*Synth. Commu.* **1987**, *17*, 1071) or dialkyl phosphonate esters (*Tetrahedron Lett.* **1983**, *24*, 4405; *Bull. Soc. Chim.* **1993**, *130*, 485).

It is envisioned that compounds of Formula I can be mixed phosphonate ester (*e.g.*, phenyl and benzyl esters, or phenyl and acyloxyalkyl esters) including the chemically combined mixed esters such as phenyl and benzyl combined prodrugs reported in *Bioorg. Med. Chem. Lett.* **1997**, *7*, 99.

Dichlorophosphonates are also useful for the preparation of various phosphonamides as prodrugs. For example, treatment of a dichlorophosphonate with an amine (*e.g.* an amino acid alkyl ester such as L-alanine ethyl ester) in the presence of a suitable base (*e.g.* triethylamine, pyridine, etc.) gives the corresponding bisphosphonamide; treatment of a dichlorophosphonate with 1-amino-3-propanol gives a cyclic 1,3-propylphosphonamide; treatment of a chlorophosphonate monophenyl ester with an aminoacid ester in the presence of a suitable base gives a substituted monophenyl monophosphonamidate. Direct couplings of a phosphonic acid with an amine (*e.g.* an amino acid alkyl ester such as L-alanine ethyl ester) are also reported to give the corresponding bisamidates under Mukaiyama conditions (*J. Am. Chem. Soc.*, **1972**, *94*, 8528).

The SATE (*S*-acetyl thioethyl) prodrugs can be synthesized by the coupling reaction of the phosphonic acids of Formula I and S-acyl-2-thioethanol in the presence of DCC, EDCI or PyBOP (*J. Med. Chem.* **1996**, *39*, 1981).

Cyclic phosphonate esters of substituted 1,3-propane diols can be synthesized by either reactions of the corresponding dichlorophosphonate with a substituted 1,3-propanediol or coupling reactions using suitable coupling reagents (*e.g.*, DCC, EDCI, PyBOP; *Synthesis* **1988**, 62). The reactive dichlorophosphonate intermediates can be prepared from the corresponding acids and chlorinating agents such as thionyl chloride (*J. Med. Chem.*, **1994**, 1857), oxalyl chloride (*Tetrahedron Lett.*, **1990**, *31*: 3261) and phosphorus pentachloride (*Synthesis*, **1974**, 490). Alternatively, these dichlorophosphonates can also be generated from disilyl esters (*Synth. Commun.*, **1987**, *17*: 1071) and dialkyl esters (*Tetrahedron Lett.*, **1983**, *24*: 4405; *Bull. Soc. Chim. Fr.*, **1993**, *130*: 485).

Alternatively, these cyclic phosphonate esters of substituted 1,3-propane diols are prepared from phosphonic acids by coupling with diols under Mitsunobu reaction conditions (*Synthesis* 1 (1981); *J.Org. Chem.* 52:6331 (1992)), and other acid coupling reagents including, but not limited to, carbodiimides (*Collect. Czech. Chem. Commun.* 59:1853 (1994); *Bioorg. Med. Chem. Lett.* 2:145 (1992); *Tetrahedron Lett.* 29:1189

(1988)), and benzotriazolyloxytris-(dimethylamino) phosphonium salts (*Tetrahedron Lett.* 34, 6743 (1993)).

Phosphonic acids also undergo cyclic prodrug formation with cyclic acetals or cyclic *ortho* esters of substituted propane-1,3-diols to provide prodrugs as in the case of carboxylic acid esters (*Helv. Chim. Acta.* 48:1746 (1965)). Alternatively, more reactive cyclic sulfites or sulfates are also suitable coupling precursors to react with phosphonic acid salts. These precursors can be made from the corresponding diols as described in the literature.

Alternatively, cyclic phosphonate esters of substituted 1,3-propane diols can be synthesized by *trans* esterification reaction with substituted 1,3-propane diol under suitable conditions. Mixed anhydrides of parent phosphonic acids generated *in situ* under appropriate conditions react with diols to give prodrugs as in the case of carboxylic acid esters (*Bull. Chem. Soc. Jpn.* 52:1989 (1979)). Aryl esters of phosphonates are also known to undergo transesterification with alkoxy intermediates (*Tetrahedron Lett.* 38:2597 (1997); *Synthesis* 968 (1993)).

One aspect of the present invention provides methods to synthesize and isolate single isomers of prodrugs of phosphonic acids of Formula I. Because phosphorus is a stereogenic atom, formation of a prodrug with a racemic substituted-1,3-propane-diol will produce a mixture of isomers. For example, formation of a prodrug with a racemic 1-(V)-substituted-1,3-propane diol gives a racemic mixture of cis-prodrugs and a racemic mixture of trans-prodrugs. In an other aspect, the use of the enantioenriched substituted-1,3-propane diol with the R-configuration gives enantioenriched R-cis-and R-trans-prodrugs. These compounds can be separated by a combination of column chromatography and/or fractional crystallization.

A. <u>Deprotection of A Phosphonate Ester</u>

Compounds of Formula I wherein X is -PO_3H_2 may be prepared from phosphonate esters using the known cleavage methods. Silyl halides are generally used to cleave various phosphonate esters and give the desired phosphonic acid upon mild hydrolysis of the resulting silyl phosphonate esters. When needed, acid scavengers (for example, HMDS) can be used for the acid sensitive compounds. Such silyl halides include TMSCl (*J. Org. Chem.* **1963**, *28*, 2975), TMSBr (*Tetrahedron Lett.* **1977**, 155) and TMSI (*J. Chem. Soc., Chem. Commu.* **1978**, 870). Alternatively, phosphonate esters can be cleaved under strong acid conditions (*Tetrahedron Lett.* **1992**, *33*, 4137;

Synthesis-Stuttgart **1993**, *10*, 955). Those phosphonate esters can also be cleaved via dichlorophosphonates prepared by treating the phosphonate esters with halogenating agents such as PCl_5, $SOCl_2$ and BF_3 (*J. Chem. Soc.* **1961**, 238) followed by aqueous hydrolysis to give the phosphonic acids. Aryl and benzyl phosphonate esters can be cleaved under hydrogenolysis conditions (*Synthesis* **1982**, 412; *J. Med. Chem.* **1985**, *28*, 1208) or metal reduction conditions (*J. Chem. Soc.* **1977**, *99*, 5118). Electrochemical (*J. Org. Chem.* **1979**, *44*, 4508) and pyrolysis (*Synth. Commu.* **1980**, *10*, 299) conditions have been used to cleave various phosphonate esters.

Introduction of A Phosphonate Group

The introduction of a phosphonate group can generally be accomplished according to known methods. Compounds of Formula I wherein T is $-O(CR^b_2)(CR^a_2)_n-$, $-S(CR^b_2)(CR^a_2)_n-$ or $-N(R^c)(CR^b_2)(CR^a_2)_n-$ may be prepared by coupling a phenol, thiophenol, or aniline with a phosphonate ester component such as $I(CR^b_2)(CR^a_2)_nP(O)(OEt)_2$, $TsO(CR^b_2)(CR^a_2)_nP(O)(OEt)_2$, or $TfO(CR^b_2)(CR^a_2)_nP(O)(OEt)_2$ in the presence of a base such as NaH, K_2CO_3, KO-t-Bu or TEA (*Tetrahedron Lett.* **1986**, *27*, 1477; *J. Chem. Soc. Perkin Tran 1* **1994**, 1987) as described in Scheme 1. Following the procedures described as above, deprotection of the phosphonate ester **2** gives the desired phosphonic acid **3**.

Compounds of Formula I wherein T is $-N(R^b)C(O)(CR^a_2)_n-$ can be prepared by coupling an aniline **1** (M = NH) with a carboxylic acid containing a phosphonate moiety $(EtO)_2P(O)(CR^a_2)_{1-2}CO_2H$ in the presence of DCC or EDC according to the known methods (for example, *J. Org. Chem.* **1977**, *42*, 2019) or converting an aniline **1** (M = NH) to an isocyanate with diphosgene followed by reacting with $P(OEt)_3$ (*J. Org. Chem.* **1956**, 1661; *Tetrahedron Lett.* **1996**, *37*, 5861). Deprotection of the phosphonate ester **2** as described above leads to the phosphonic acid **3**.

For compounds of Formula I wherein T is $-(CR^a_2)_k-$, the phosphonate group can be introduced by a number of known methods. For example, the coupling reaction of a phenyl bromide (*J. Org. Chem.* **1999**, *64*, 120), iodide (*Phosphorus Sulfur* **1997**, *130*, 59) or triflate (*J. Org. Chem.* **2001**, *66*, 348) with diethyl phosphonate in the presence of a Pd catalyst is widely used within the art (when k is 0). Other methods such as Michaelis-Arbuzov reaction (*Chem. Rev.* **1981**, *81*, 415) can also be an efficient way to introduce the phosphonate group by coupling a benzyl or arylalkyl halide with triethyl phosphonate (when m is 1-3).

For compounds of Formula I wherein T is $-(CR^a_2)_n-CR^b=CR^b-$, the phosphonate group can be introduced by coupling an aldehyde and tetraethyl methylenediphosphonate in the presence of a base such as NaH, NaOH or KO-t-Bu (*Tetrahedron Lett.* **1988**, *29*, 3007). For compounds of Formula I wherein T is $-CR^b=CR^b-(CR^a_2)_n-$ or $-(CR^a_2)-CR^b=CR^b-(CR^a_2)-$, the phosphonate group can be introduced by Michaelis-Arbuzov reaction of the corresponding olefinic halide with triethyl phosphite.

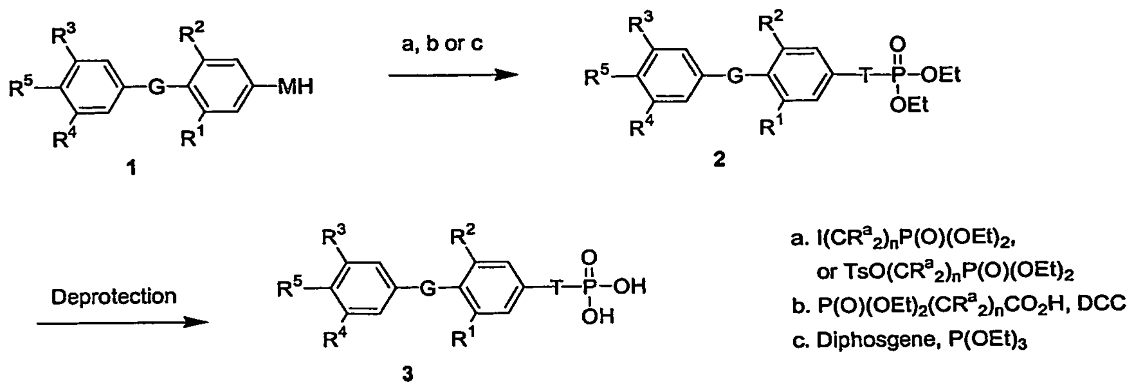
For compounds of Formula I wherein T is $-(CR^a_2)_m(CO)-$, the phosphonate group can be introduced by reacting diethyl phosphite with an acid chloride (*J. Org, Chem.* **1964**, *29*, 3862; *Tetrahedron* **1998**, *54*, 12233) or an aldehyde followed by oxidation (*Tetrahedron* **1996**, *52*, 9963). Also, this type of compounds can be transformed into the compounds of Formula I wherein T is $-(CR^a_2)_nCH(NR^bR^c)-$ according to known procedures (*Tetrahedron Lett.* **1996**, *37*, 407).

For compounds of Formula I wherein T is $-(CO)(CR^a_2)_m-$, the phosphonate group can be introduced by a number of known methods such as reacting a substituted benzoyl chloride with diethylphosphonoacetic acid (*Synthetic Commu.* **2000**, *30*, 609) or a phosphonate copper reagent (*Tetrahedron Lett.* **1990**, *31*, 1833). Alternatively, coupling of triethyl phosphonate with a silyl enol ether (*Synthetic Commu.* **1994**, *24*, 629) or a α-bromobenzophenone (*Phosphorus Sulfur* **1994**, *90*, 47) can also introduce the phosphonate group.

For compounds of Formula I wherein T is $-C(O)NH(CR^b_2)(CR^a_2)_p-$, the phosphonate group can be introduced by coupling reaction of a substituted benzoic acid and an aminophosphonate according to the standard amide bond formation methods (*Tetrahedron Lett.* **1990**, *31*, 7119; *Tetrahedron Lett.* **1989**, *30*, 6917; *J. Org. Chem.* **1993**, *58*, 618).

For compounds of Formula I wherein T is $-(CR^a_2)C(O)(CR^a_2)_n-$ or $(CR^a_2)_nC(O)(CR^a_2)$, the phosphonate group can be introduced by reacting a benzyl bromide with a functionalized phosphonate (*Tetrahedron Lett.* **1989**, *30*, 4787). Alternatively, a coupling reaction of a substituted phenylacetate and methylphosphonate also yields the desired product (*J. Am. Chem. Soc.* **1999**, *121*, 1990).

Scheme 1

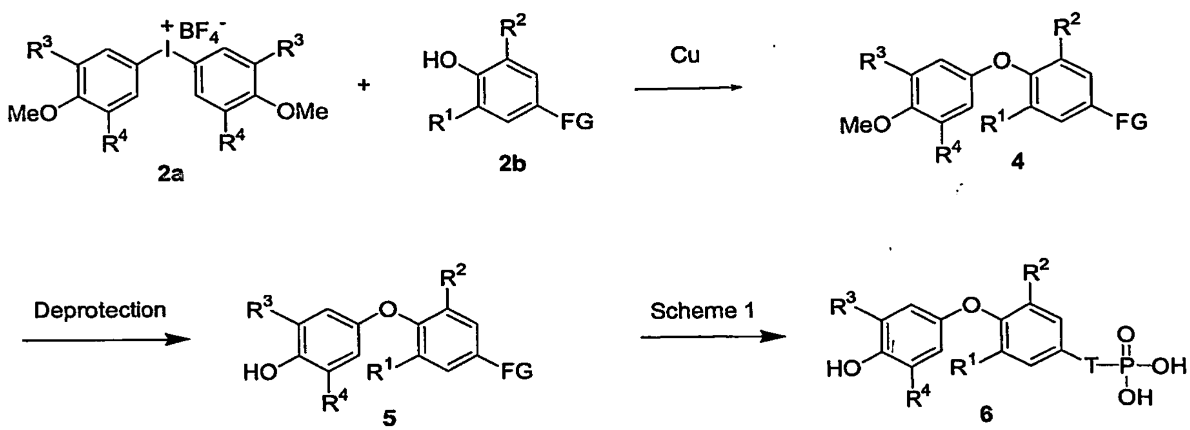


M = O, S, NH
T = $O(CR^a{}_2)_n$, $S(CR^a{}_2)_n$, $NR^b(CR^a{}_2)_n$, $NR^b(CO)(CR^a{}_2)_n$

Construction of The Diaryl Ring

Compounds of Formula I wherein G is –O- can be prepared according to known methods. As described in Scheme 2, **2a** is reacted with **2b** at room temperature in the presence of Cu powder and a suitable base such as TEA, diisopropylamine or pyridine to provide the coupling product **4** (*J. Med. Chem.* **1995**, *38*, 695). Deprotection of the methoxy group with suitable reagents such as boron tribromide, boron trichloride or boron trifluoride in CH_2Cl_2 gives the intermediate **5**. Introduction of the phosphonate group followed by deprotection of the phosphonate ester as described in Scheme 1 leads to the desired phosphonic acid **6**. Those skilled in the art can use other known methods such as coupling of an arylboronic acid and a phenol in the presence of $Cu(OAc)_2$ (*Tetrahedron Lett.* **1998**, *39*, 2937), nucleophilic substitution of a fluorobenzene (*Synthesis-Stuttgart* **1991**, *1*, 63) or iodobenzene (*J. Am. Chem. Soc.* **1997**, *119*, 10539) with a phenol and coupling of a bromobenzene with a phenol in the presence of $Pd_2(dba)_3$ (*Tetrahedron Lett.* **1997**, *38*, 8005) to form the diaryl ether system.

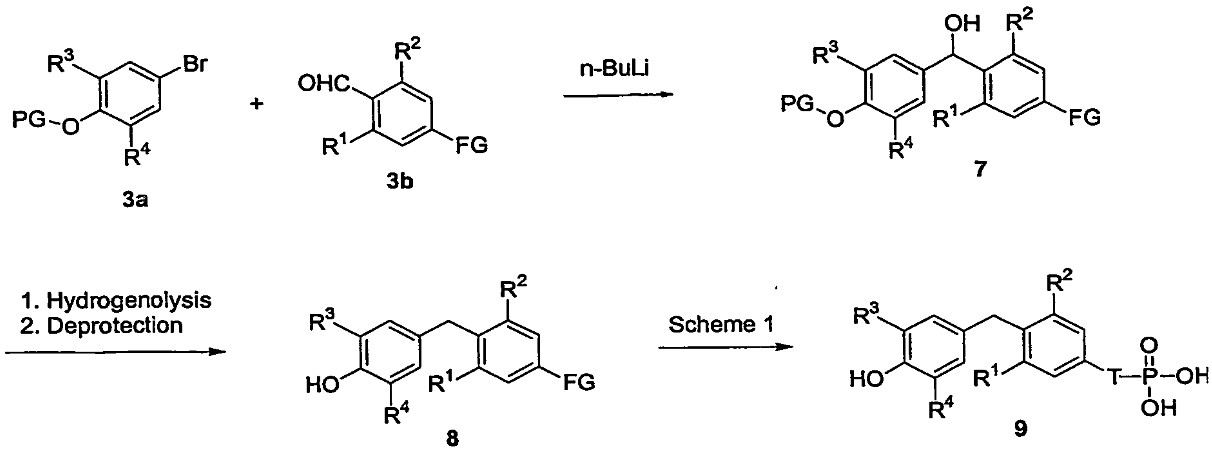
Scheme 2



FG = functional group that can be transformed into T

For compounds of Formula I wherein G is -CH_2-, the installation of the diaryl ring can be accomplished by a number of known methods. For example, as described in Scheme 3, benzyl alcohol **7** is formed by treatment of **3a** with n-BuLi at –78 °C in THF followed by reacting with **3b** (*Bioorg. Med. Chem. Lett.* **2000,** *10*, 2607). Hydrogenolysis with Pd-C or dehydroxylation of benzyl alcohol **7** by $NaBH_4$ (*Synthetic Commu.* **1987,** *17*, 1001) and $(i\text{-}Bu)_3Al$ (*Synthesis* **1987**, 736) followed by removal of the protecting group gives the diaryl intermediate **8**. Phosphonic acid **9** is formed from **8** according to the same procedures as described in Scheme 1. Alternatively, coupling of benzyl bromide with an aryl Grignard reagent (*Tetrahedron Lett.* **1981,** *22*, 2715), an arylboronic acid (*Tetrahedron, Lett.* **1999,** *40*, 7599) or a zinc reagent (*Chem. Lett.* **1999,** *11*, 1241) and reduction of a diaryl ketone (*J. Org. Chem.* **1986,** *51*, 3038) are all widely used methods for the construction of the diaryl ring.

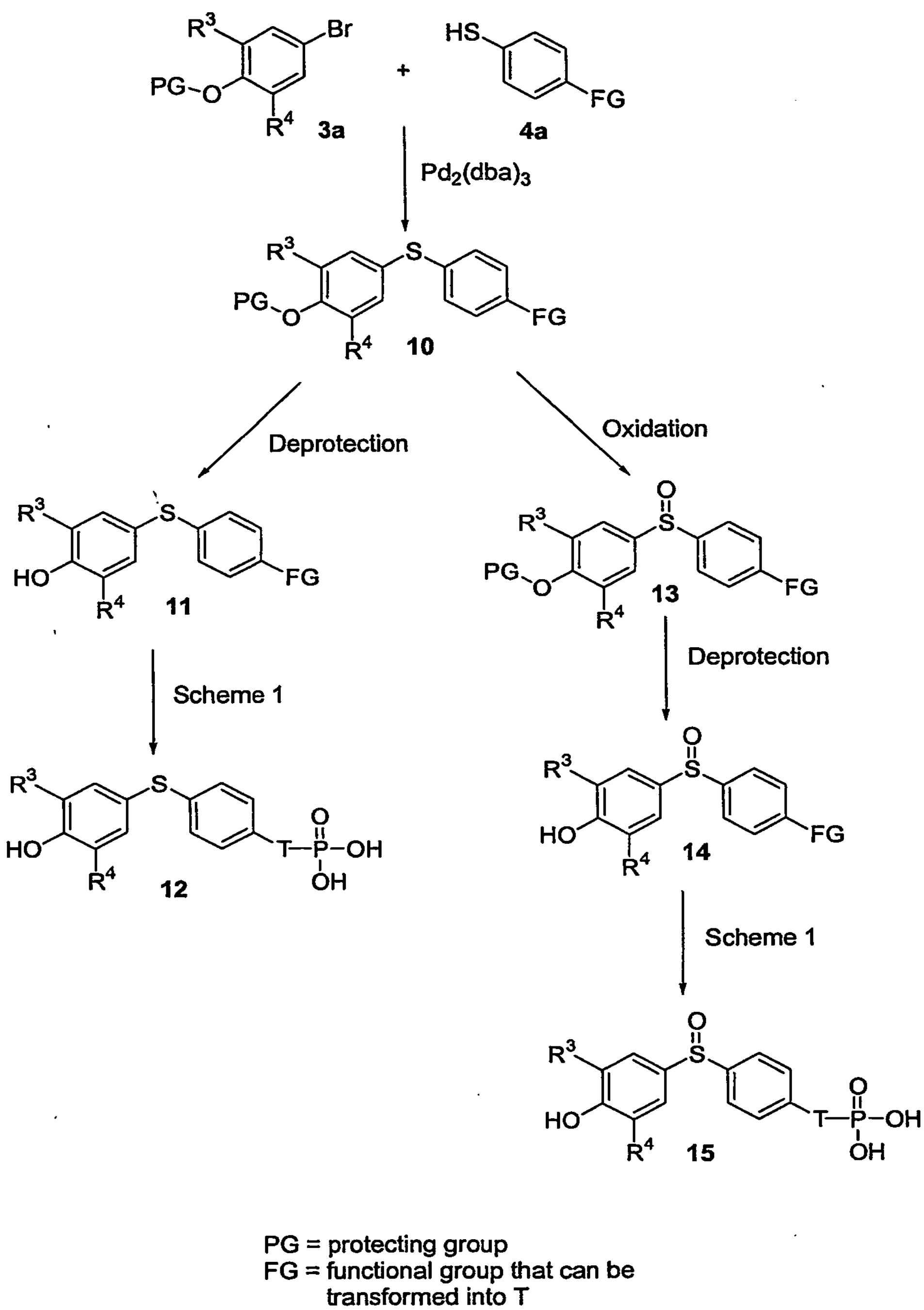
Scheme 3



PG = protecting group
FG = functional group that can be transformed into T

For compounds of Formula I wherein G is –S-, -S(=O)- or -S(=O_2)-, the formation of the diaryl ring can be achieved according to known methods. As illustrated in Scheme 4, **3a** can be reacted with **4a** in the presence of a catalyst such as $Pd_2(dba)_3$ or CuBr to provide the diaryl sulfide **10** (*Tetrahedron* **2001**, *57*, 3069; *Tetrahedron Lett.* **2000**, *41*,1283). Phosphonic acid **12** is formed from **10** after removal of the protecting groups followed by the same procedures as described in Scheme 1. The diaryl sulfide **10** can also be converted to the sulfoxide **13** according to known methods (*Synthetic Commu.* **1986**, *16*, 1207; *J. Org. Chem.* **1997**, *62*, 4253; *Tetrahedron Lett.* **1990**, *31*, 4533), which leads to the phosphonic acid **15** following the same procedures as described in Scheme 1. Also, the biaryl sulfide **10** can be converted to the sulfone (*Tetrahedron Lett.* **1991**, *32*, 7353; *J. Prakt. Chem.* **1942**, 160) which leads to the phosphonic acid (G is –S(=O_2)-) following the same procedures as described above. In addition, nucleophilic substitution of chlorobenzene and bromobenzene with a thiol is also an efficient way to install the diaryl sulfide ring (*J. Med. Chem.* **1988**, *31*, 254; *J. Org. Chem.* **1998**, *63*, 6338).

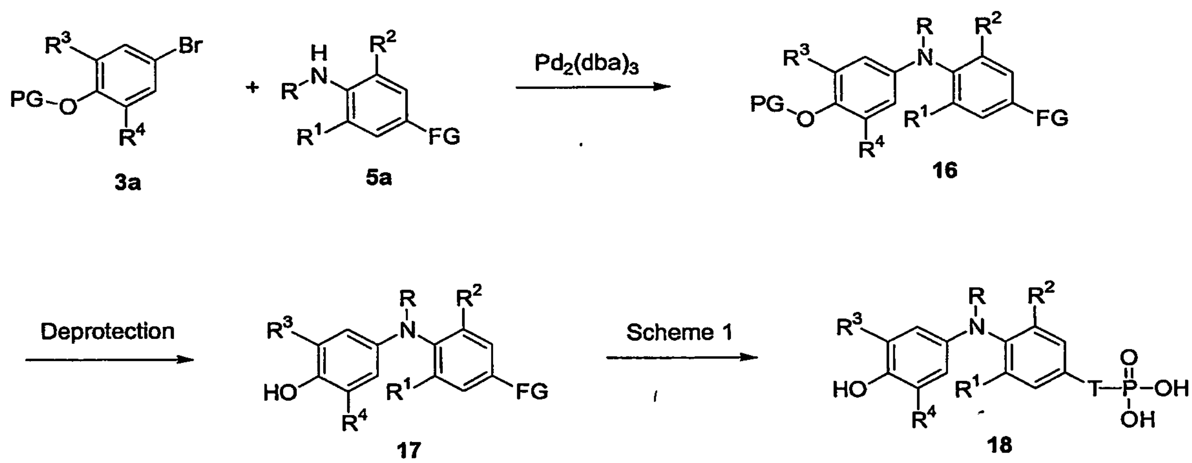
Scheme 4



For compounds of Formula I wherein G is –NH- or –N(C_1-C_4 alkyl)-, the diarylamine backbone can be formed by a number of known methods. Among those conditions, one widely used by those skilled in the art is the coupling reaction of an aniline with an aryl bromide (*J. Org. Chem.* **1999**, *64*, 5575; *J. Org. Chem.* **1997**, *62*,

6066; *Tetrahedron Lett.* **1996,** *37*, 6993; *Org. Lett.* **1999,** *1*, 2057) or an aryl tosylate (*J. Org. Chem.* **1997,** *62*, 1268) in the presence of a catalyst such as $PdCl_2$ or $Pd_2(dba)_3$. As illustrated in Scheme 5, the diarylamine intermediate **16** can be prepared by coupling of bromide **3a** and aniline **5a** in the presence of $Pd_2(dba)_3$. After removal of the protecting group, the diarylamine **17** is converted to the phosphonic acid **18** following the same procedures as described in Scheme 1. Alternatively, coupling of an aniline and aryl halide using other catalysts such as copper-bronze (*Org. Synth.* **1943,** *2*, 446; *J. Org. Chem.* **1955,** 20) and $Cu(OAc)_2$ (*J. Med. Chem.* **1986,** *4*, 470; *Synthetic Commu.* **1996,** *26*, 3877) to construct the diarylamine backbone is also a feasible approach.

Scheme 5

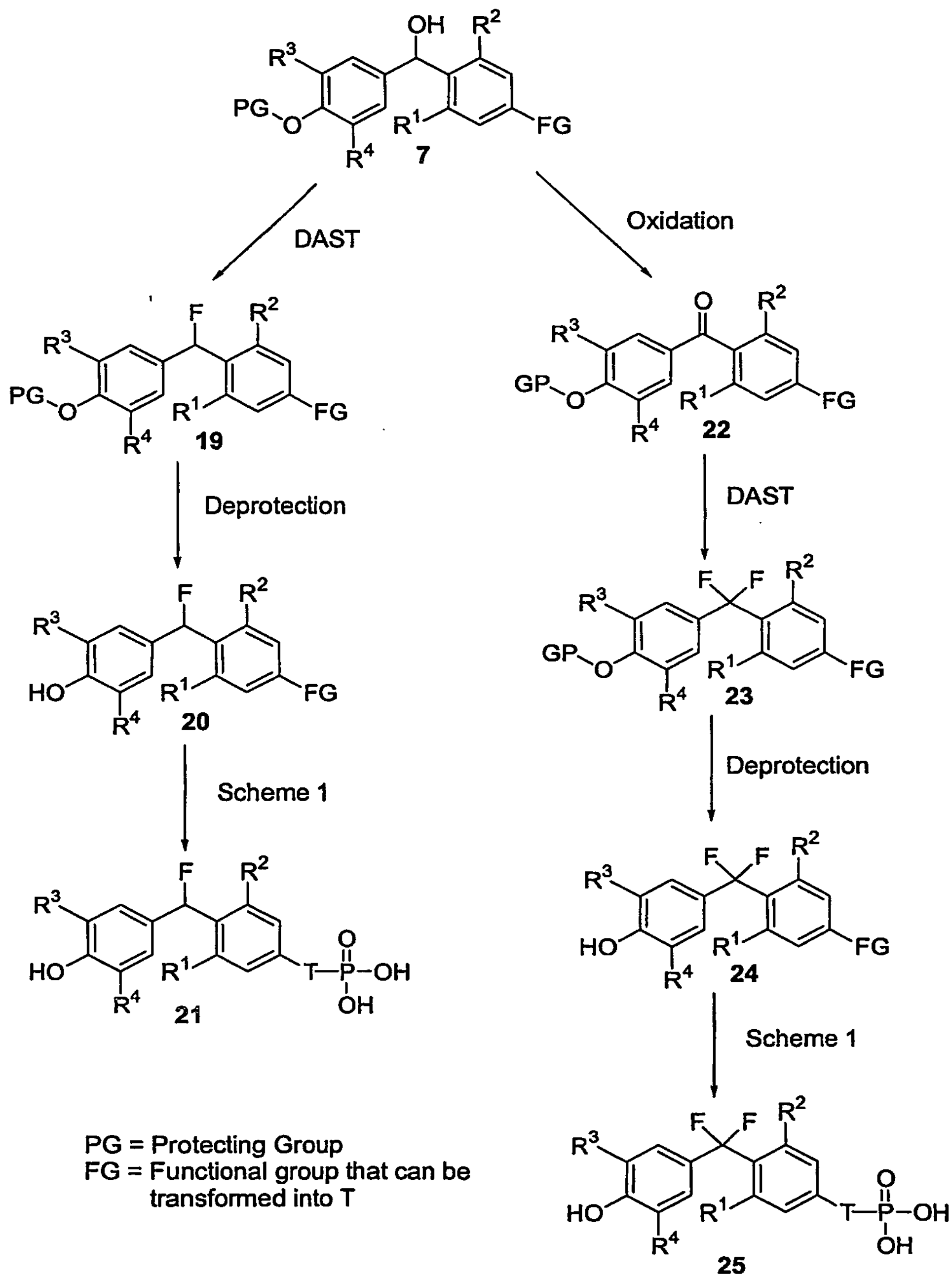


R = H, C_1-C_4 alkyl
PG = Protecting Group
FG = Functional group that can be transformed into T

For compounds of Formula I wherein G is –CHF- or -CF_2-, the diaryl backbone can be established from the benzyl alcohol **7**. Accordingly, as described in Scheme 6, benzyl alcohol **7** can be converted to the benzyl fluoride **19** by reacting with DAST in CH_2Cl_2 according to known procedures (*J. Chem. Soc., Chem. Commu.* **1981,** *11*, 511; *Tetrahedron Lett.* **1995,** *36*, 6271; *Tetrahedron* **1988,** *14*, 2875). Also, the benzyl alcohol **7** can be easily oxidized to the benzophenone **22** according to known methods such as MnO_2 oxidation, PCC oxidation, Swern oxidation and Dess-Martin oxidation, which is subsequently converted to the benzyl difluoride **23** by treatment with DAST (*J. Fluorine* **1993,** *61*, 117) or other known reagents (*J. Org. Chem.* **1986,** *51*, 3508;

Tetrahedron **1999**, *55*, 1881). After removal of the protecting groups, the benzyl fluoride **20** and difluoride **24** are converted to the desired phosphonic acids following the same procedures as described in Scheme 1.

Scheme 6

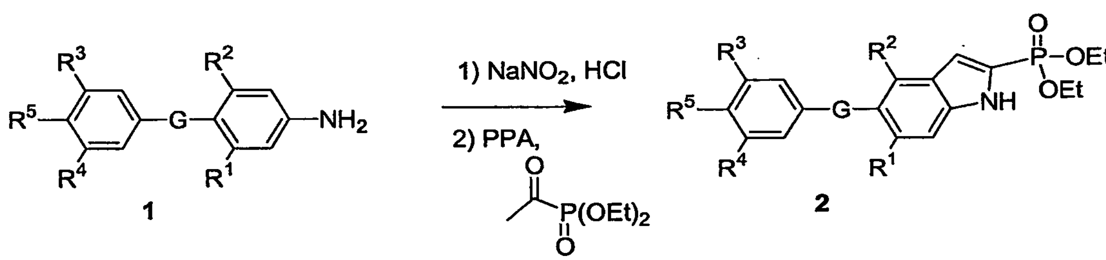


Compounds of Formula I wherein G is -CH(OH)- or -C(O)- can be prepared from the intermediates **7** and **22**. Removal of the protecting groups of **7** and **22** followed by introduction of the phosphate and deprotection as described in Scheme 1 provides the desired phosphonic acids of Formula I.

Synthesis of compounds of Formula II

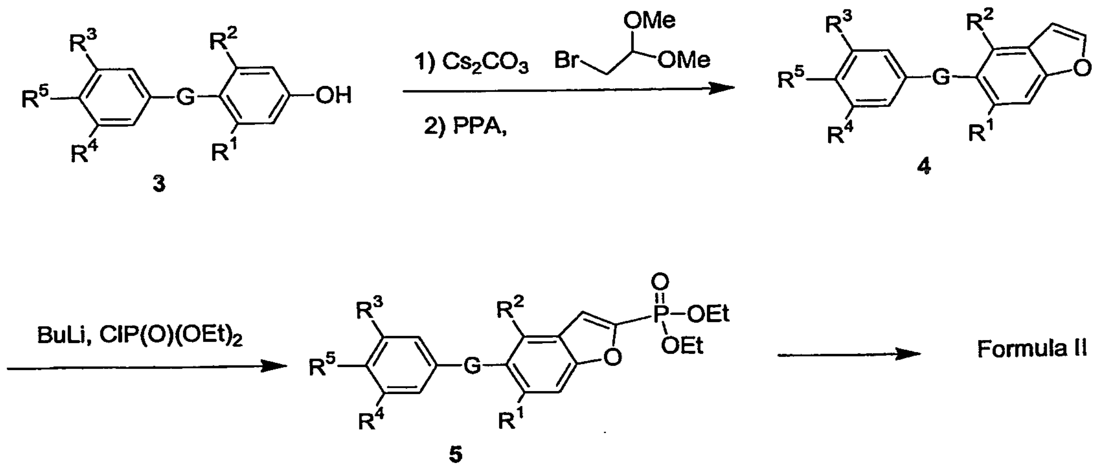
The synthesis of compounds of Formula II where A is –NH- and B is –CH- or -C-alkyl- can be accomplished from the corresponding amino diaryl precursor **1** using the well-known, to those skilled in the art, Fisher indole synthesis (Scheme 6a) (*Phosphorus and Sulfur*, **1988**, Vol. 37, pp 41-63). Alternatively, the aryl-indole scaffold is constructed using the procedures previously described and the phosphonic acid moiety is introduced by making the anion next to the nitrogen of the indole derivative, protected at the nitrogen, with a base such as BuLi and quenching the anion with diethyl chlorophosphate. Further protecting group and functional group manipulations of intermediates **2** provide compounds of Formula II.

Scheme 6a



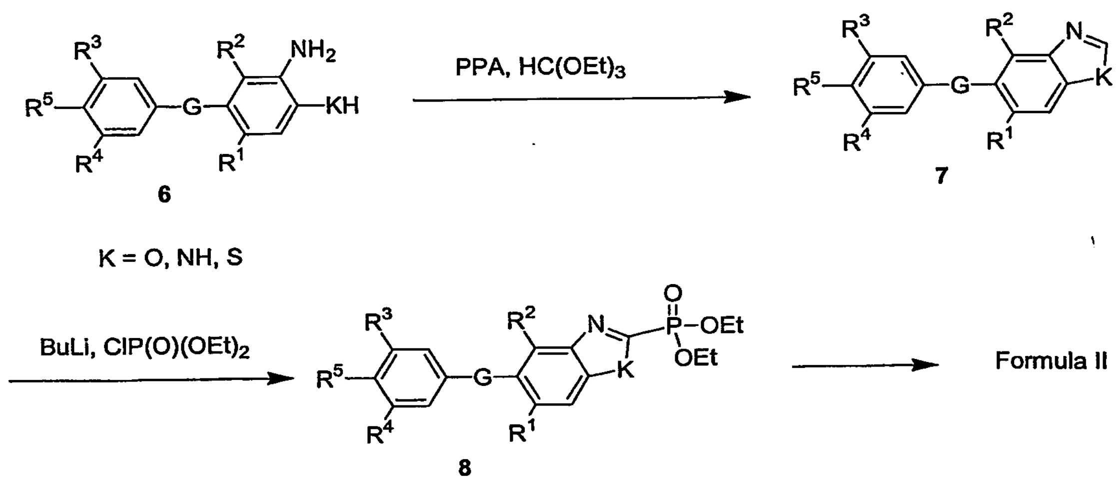
Compounds of Formula II where A is –O- and B is –CH- are synthesized from the corresponding diaryl phenol precursor **3** and ring cyclization with the dimethylacetal of bromoacetaldehyde to give benzofuran **4** (Scheme 6b) (*J. Cem. Soc., Perkin Trans. 1*, 1984, 4, 729). The phosphonic acid moiety can then be introduced by making the anion next to the oxygen of the benzofuran with a base such as BuLi and quenching the anion with diethyl chlorophosphate to provide phosphonate **5**. Further protecting group and functional group manipulations of intermediate **5** provides compounds of Formula II.

Scheme 6b



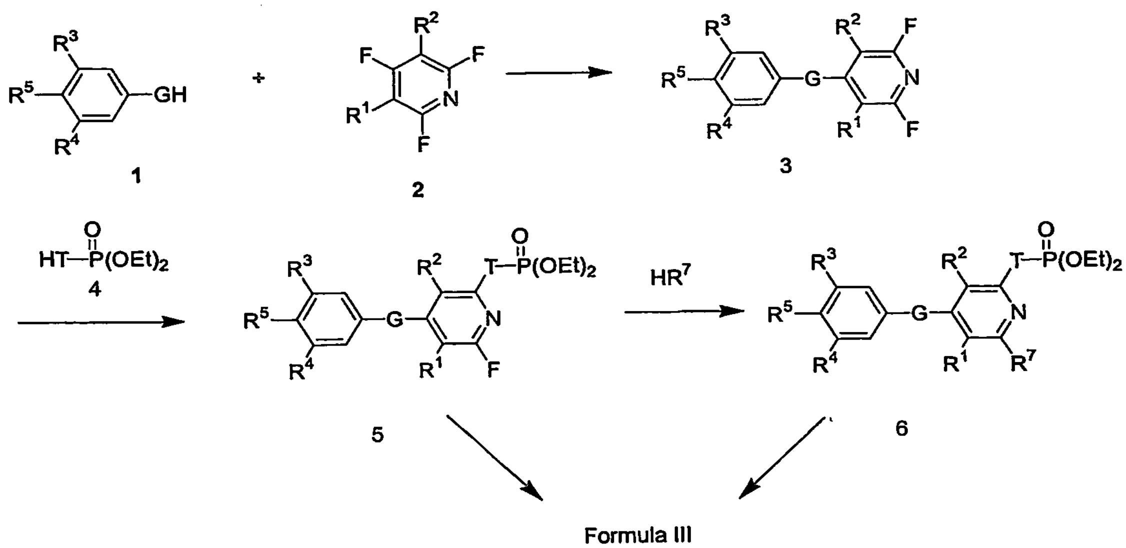
Compounds of Formula II where A is –NH-, -O- or –S- and B is –N- can be made from condensation of the corresponding diaryl precursor **6** with an orthoformate such as triethyl orthoformate in presence of acid to give heterocycle **7** (*Org. Prep. Proced. Int.*, **1990**, 22(5), 613-618). The phosphonic acid moiety can then be introduced by making the anion at the 2-position of the heterocycle **7** with a base such as BuLi and quenching the anion with diethyl chlorophosphate to give phosphonate **8**. Further protecting group and functional group manipulations of intermediates **8** provide compounds of Formula II.

Scheme 6c



Synthesis of compounds of Formula III

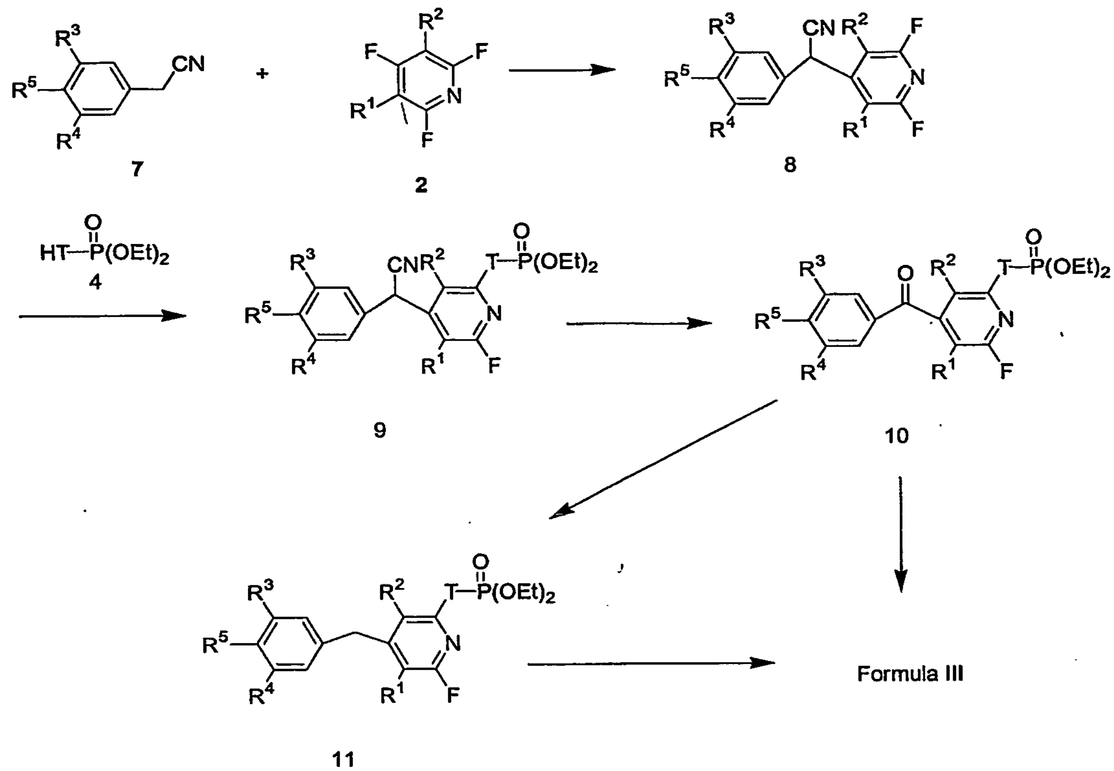
Scheme 6d



The general synthesis of compounds of Formula III wherein G is –O-, -S- or –NH- utilizes the displacement of an appropriately substituted phenol, thiophenol or aniline **1** with a pentasubstituted pyridine such as 3,5-dichloro-2,4,6-trifluoro-pyridine **2** to provide intermediate **3** (Scheme 6d) (*Org. Prep. Proced. Int.*, **2000**, 32(5), 502-504). Subsequent displacement of the 2-fluoro and 6-fluoro substituents on the pyridine ring with nucleophiles **4** and HR^7 sequentially provide intermediates **5** and **6**. Examples of suitable nucleophiles, include but are not limited to, diethyl hydroxymethyl-phosphonate and diethyl aminomethyl-phosphonate. Example of reactants HR^7, include but are not limited to, alkylthiol, sodium alkoxide, alkylamine or benzylamine. Compounds of Formula III where G is -S(=O)- and -S(=O)$_2$- can be derived from intermediates **5** and **6** when G is

–S- via oxidation with an oxidizing agent such as mCPBA. Further protecting group and functional group manipulations of intermediates **5** and **6** will provide compounds of Formula III.

Scheme 6e



Compounds of Formula III wherein G is $-CH_2-$ or $-C(O)-$ are synthesized according to scheme 6e. Condensation of benzyl cyanide **7** with pentasubstituted pyridine **2** provide intermediate **8**. Displacement of 2-fluoro with reagent **4** gives intermediate **9**. Oxidation of benzyl cyanide **9** provides keto derivative **10** which after deprotection and functional group manipulation gives a compound of Formula III. Alternatively, reductive deoxygenation of keto intermediate followed by deprotection and functional group manipulation gives a compound of Formula III.

Preparation of Key Precursors

A. Preparation of Compounds with Substituents on the Ring

Starting material and key intermediates required for the synthesis of the compounds in this invention are either commercially available or prepared using an existing method in the literature or a modification of a known method. Syntheses of some of those compounds are described herein.

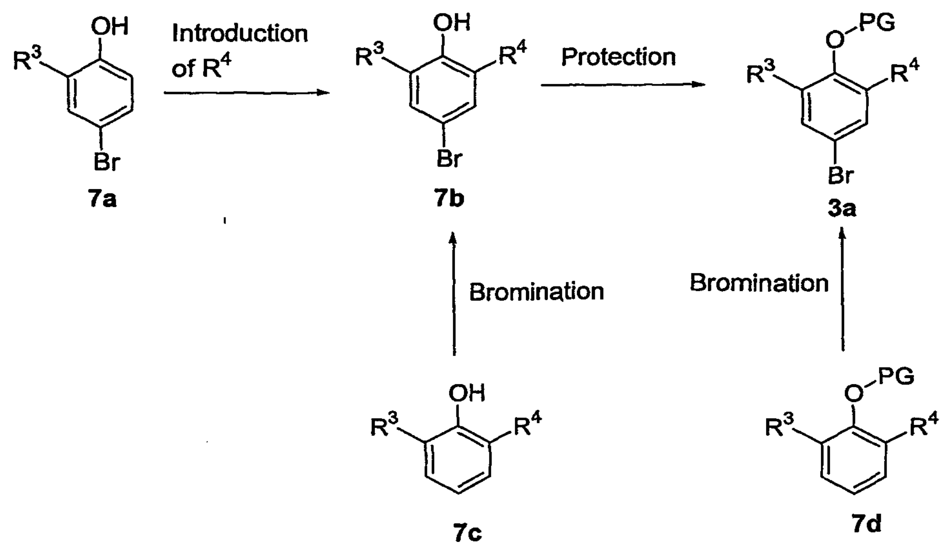
Precursor **2a** is prepared by reacting an anisole with iodine trifluoroacetate according to the reference procedures (*J. Med. Chem.* **1995**, *38*, 695). Anisoles with

different R^3 and R^4 groups are either commercially available or can be prepared according to the literature procedures (*e.g.*, *J. Med. Chem.* **1989**, *32*, 320).

Starting material **2b** is either commercially available or prepared according to known procedures. For example, compounds of **2b** wherein FG is NH_2-derived group can be prepared by reacting **3a** with benzophenone imine in the presence of a Pd catalyst such as $Pd_2(dba)_3$ or $Pd(OAc)_2$ (*Tetrahedron Lett.* **1997**, *38*, 6367; *J. Am. Chem. Soc.* **1998**, *120*, 827). Compounds of **2b** wherein FG is S-derived group can be prepared by reacting a feasible 4-aminoanisole with $NaNO_2$ and potassium ethyl xanthate (*J. Am. Chem. Soc.* **1946**, 68; *Heterocycles* **1987**, *26*, 973).

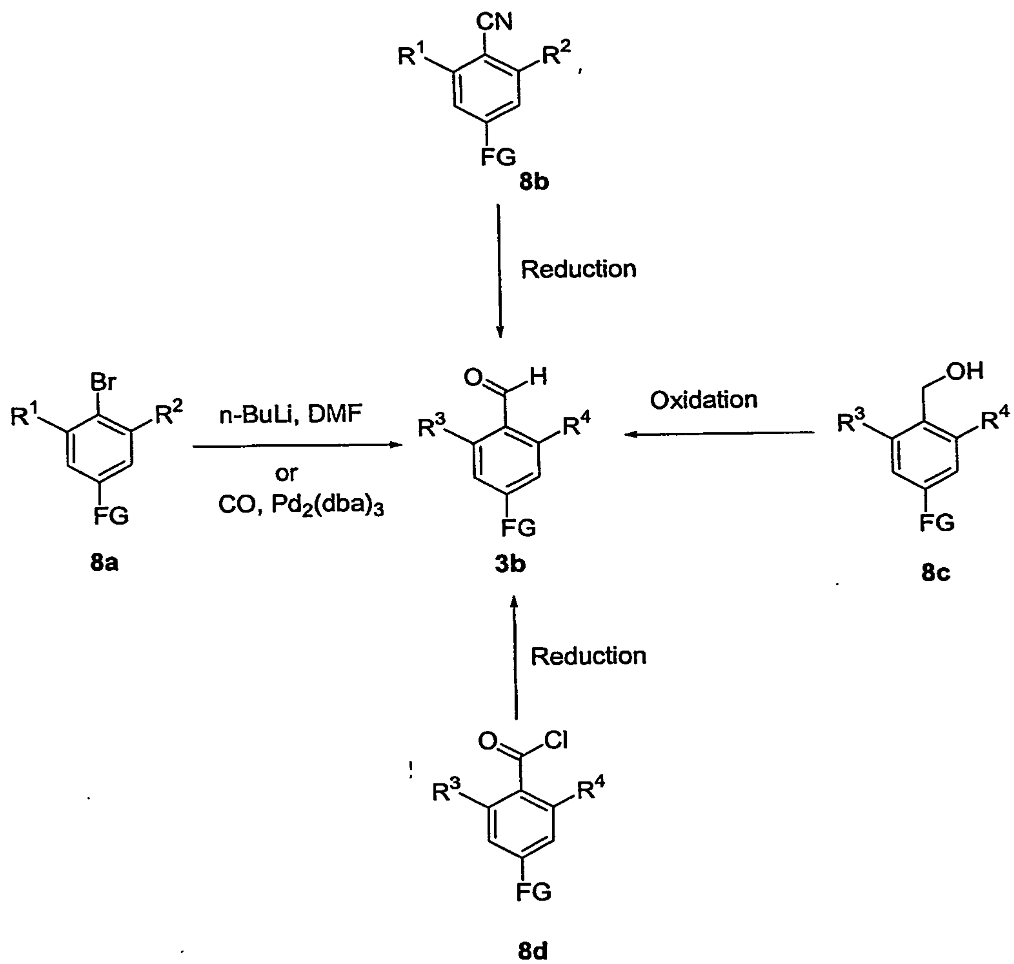
The useful precursor **3a** can either be commercially available reagents or prepared according to the existing methods. As described in Scheme 7, a simple protection of commercially available 4-bromophenol **7b** with different R^3 and R^4 groups according to the procedures known in the art leads to **3a**. Compound **3a** can also be prepared by bromination of protected phenol **7d** (*J. Org. Chem.* **1988**, *53*, 5545; *J. Org. Chem.* **1994**, *59*, 4473; *Synthesis-Stuttgart* **1986**, *10*, 868). Introduction of various R^3 and R^4 groups to 4-bromophenol **7a** can be carried out to give **7b** which leads to **7a** after protection (*Tetrahedron Lett.* **1995**, *36*, 8453; *J. Heterocyclic Chem.* **1991**, *28*, 1395; *J. Fluorine Chem.* **1988**, *40*, 23; *Synthesis-Stuttgart* **1999**, *11*, 1878; *Synthetic Commu.* **1986**, *16*, 681). **7b** can also be prepared by the bromination of phenol **7c** (*J. Comb. Chem.* **2000**, *2*, 434; *Chem. Soc. JPN.* **1988**, *61*, 2681; *Synthesis-Stuttgart* **1992**, *5*, 467; *Org. Synth.* **1993**, *72*, 95).

Scheme 7



A number of methods are available for the preparation of the benzaldehyde **3b**. As illustrated in Scheme 8, bromobenzene **8a** can be converted to benzaldehyde **3b** by reacting with DMF (*Aust. J. Chem.* **1998,** *51*, 177; *Bioorg. Med. Chem. Lett.* **2000,** *10*, 2607) or carbon monoxide in the presence of a palladium catalyst (*Bull. Chem. Soc. Jpn* **1994,** *67*, 2329). **3b** may be formed by oxidation of benzyl alcohol **8c** using common methods such as MnO_2 oxidation, PCC oxidation, Swern oxidation and Dess-Martin oxidation. Reduction of benzonitrile **8b** and benzoyl chloride **8d** also produces benzaldehyde **3b** (*Org. Synth.* **1995,** *3*, 551; *J. Org. Chem.* **1981,** *46*, 602).

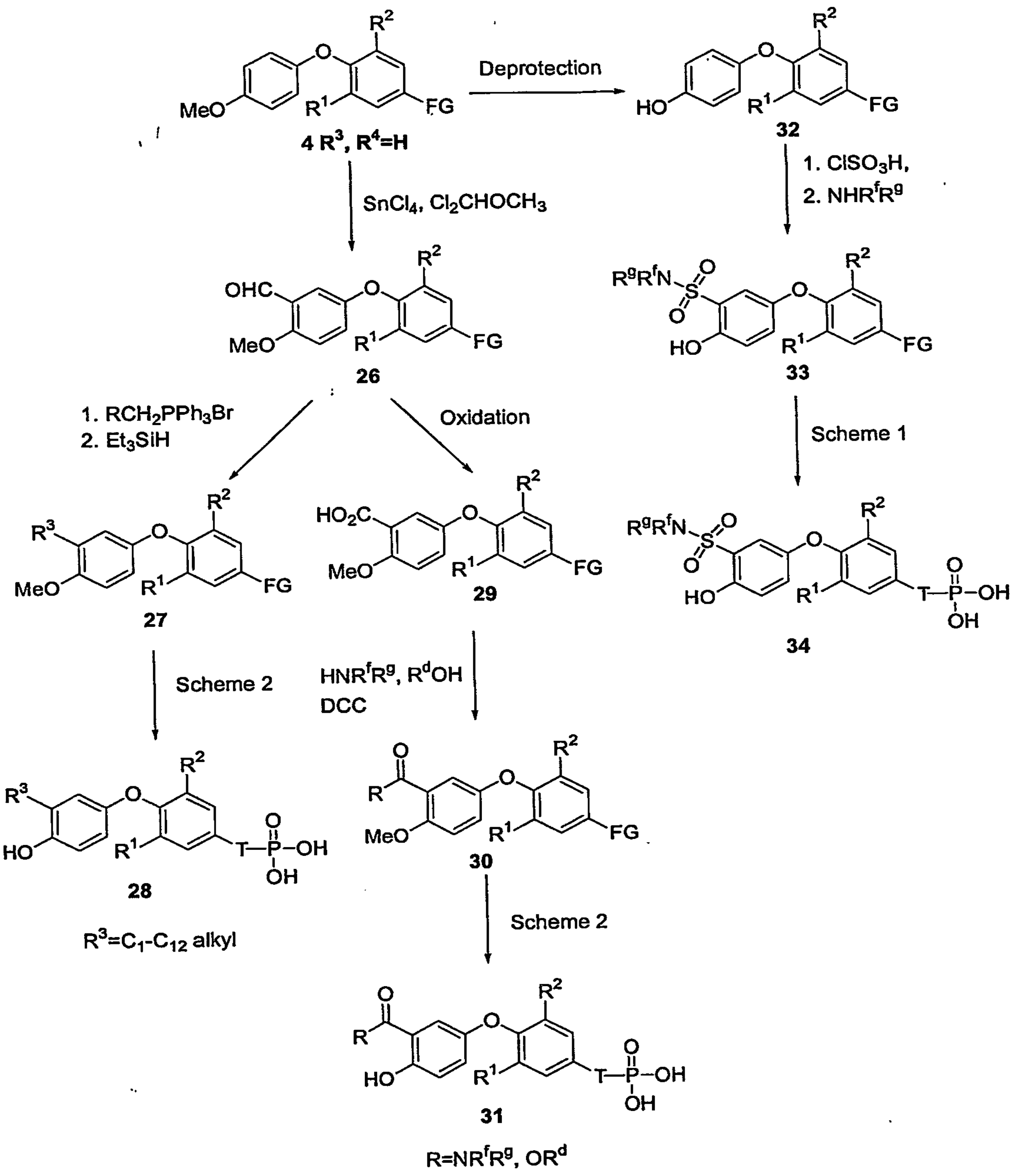
Scheme 8



For some of the compounds of Formula I, the R^3 and R^4 groups can be introduced after the biaryl ring backbone is installed. As illustrated in Scheme 9, the intermediate **4** (R^3, R^4=H) is converted to the benzylaldehyde **26** upon treatment with $SnCl_4$ and methoxymethyl dichloride. Various alkyl groups (C_1-C_{12}) are introduced by reacting the benzylaldehyde **26** with a Wittig reagent followed by the reduction of the resulting alkene with Et_3SiH to afford the intermediate **27** (*J. Med. Chem.* **1988**, *31*, 37). Also, benzylaldehyde **31** can be oxidized by $NaOCl_2$ to give the benzoic acid **29** (*Bioorg. Med. Chem. Lett.* **2003**, *13*, 379) which can be reacted with an alcohol or amine under standard conditions to give the ester or amide **30**. Intermediates **27** and **30** can be converted to the corresponding phosphonic acids **28** and **33** following the same procedures as described in Scheme 2. In addition, deprotection of intermediate **4** provides the phenol **32** which can be converted to a variety of sulfonamides **33** upon treatment with $ClSO_3H$ and an

amine. Phosphonic acids ($R^3 = S(=O)_2NR^fR^g$) can be formed following the same procedures as described in Scheme 1.

Scheme 9



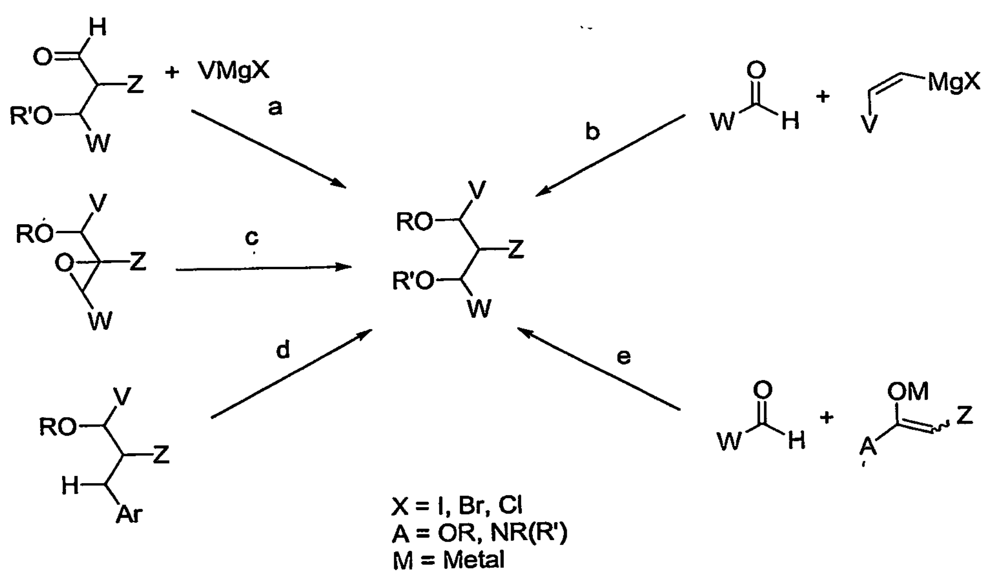
B. Preparation of 1,3-Diols

Various methods can be used to prepare 1,3-propanediols such as 1-substituted, 2-substituted, 1,2- or 1,3-annulated 1,3-propanediols.

1. 1-Substituted 1,3-propanediols

1,3-Propanediols useful in the synthesis of compounds in the present invention can be prepared using various synthetic methods. As described in Scheme 10, additions of an aryl Grignard to a 1-hydroxy-propan-3-al give 1-aryl-substituted 1,3-propanediols (path a). This method is suitable for the conversion of various aryl halides to 1-arylsubstituted-1,3-propanediols (*J. Org. Chem.* **1988,** *53,* 911). Conversions of aryl halides to 1-substituted 1,3-propanediols can also be achieved using Heck reactions (*e.g.*, couplings with a 1,3-diox-4-ene) followed by reductions and subsequent hydrolysis reactions (*Tetrahedron Lett.* **1992,** *33,* 6845). Various aromatic aldehydes can also be converted to 1-substituted-1,3-propanediols using alkenyl Grignard addition reactions followed by hydroboration-oxidation reactions (path b).

Scheme 10



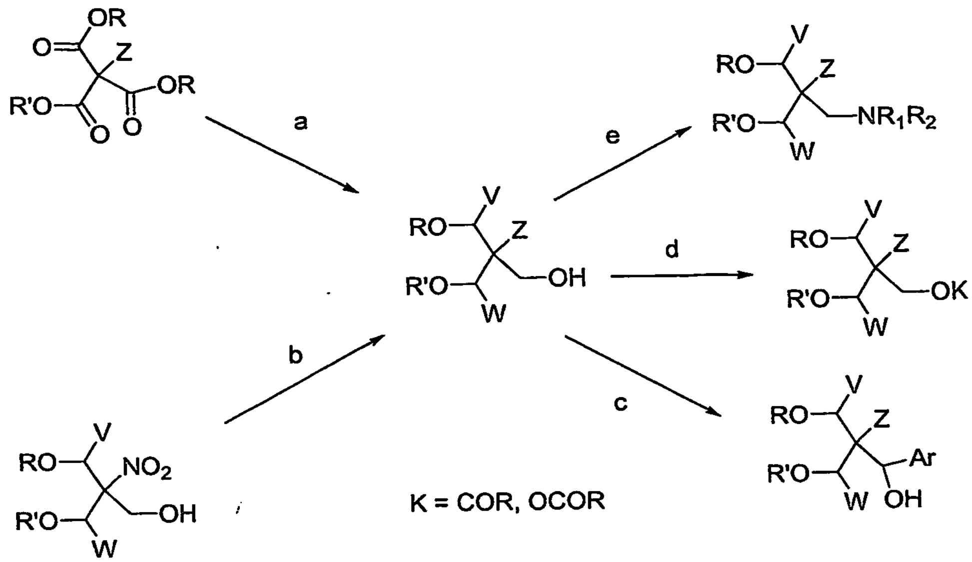
Aldol reactions between an enolate (*e.g.*, lithium, boron, tin enolates) of a carboxylic acid derivative (*e.g.*, tert-butyl acetate) and an aldehyde (*e.g.*, the Evans's aldol reactions) are especially useful for the asymmetric synthesis of enantioenriched 1,3-propanediols. For example, reaction of a metal enolate of *t*-butyl acetate with an aromatic aldehyde followed by reduction of the ester (path e) gives a 1,3-propanediol (*J.*

Org. Chem. **1990**, *55* 4744). Alternatively, epoxidation of cinnamyl alcohols using known methods (*e.g.*, Sharpless epoxidations and other asymmetric epoxidation reactions) followed by reduction reactions (*e.g.*, using Red-Al) give various 1,3-propanediols (path c). Enantioenriched 1,3-propanediols can be obtained via asymmetric reduction reactions (*e.g.*, enantioselective borane reductions) of 3-hydroxy-ketones (*Tetrahedron Lett.* **1997**, *38* 761). Alternatively, resolution of racemic 1,3-propanediols using various methods (*e.g.*, enzymatic or chemical methods) can also give enantioenriched 1,3-propanediol. Propan-3-ols with a 1-heteroaryl substituent (*e.g.*, a pyridyl, a quinolinyl or an isoquinolinyl) can be oxygenated to give 1-substituted 1,3-propanediols using N-oxide formation reactions followed by a rearrangement reaction in acetic anhydride conditions (path d) (*Tetrahedron* **1981**, *37*, 1871).

2. <u>2-Substituted 1,3-propanediols</u>

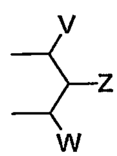
A variety of 2-substituted 1,3-propanediols useful for the synthesis of compounds of Formula I can be prepared from various other 1,3-propanediols (*e.g.*, 2-(hydroxymethyl)-1,3-propanediols) using conventional chemistry (*Comprehensive Organic Transformations*, VCH, New York, **1989**). For example, as described in Scheme 11, reductions of a trialkoxycarbonylmethane under known conditions give a triol via complete reduction (path a) or a bis(hydroxymethyl)acetic acid via selective hydrolysis of one of the ester groups followed by reduction of the remaining two other ester groups. Nitrotriols are also known to give triols via reductive elimination (path b) (*Synthesis* **1987**, *8*, 742). Furthermore, a 2-(hydroxymethyl)-1,3-propanediol can be converted to a mono acylated derivative (*e.g.*, acetyl, methoxycarbonyl) using an acyl chloride or an alkyl chloroformate (*e.g.*, acetyl chloride or methyl chloroformate) (path d) using known chemistry (*Protective Groups In Organic Synthesis* ; Wiley, New York, **1990**). Other functional group manipulations can also be used to prepare 1,3-propanediols such as oxidation of one the hydroxymethyl groups in a 2-(hydroxymethyl)-1,3-propanediol to an aldehyde followed by addition reactions with an aryl Grignard (path c). Aldehydes can also be converted to alkyl amines via reductive amination reactions (path e).

Scheme 11

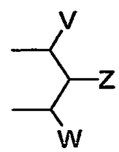


3. <u>Annulated 1,3-propane diols</u>

Compounds of Formula I wherein V and Z or V and W are connected by four carbons to form a ring can be prepared from a 1,3-cyclohexanediol. For example, *cis, cis*-1,3,5-cyclohexanetriol can be modified to give various other 1,3,5-cyclohexanetriols which are useful for the preparations of compounds of Formula I wherein R^{11} and R^{11} together are



wherein together V and W are connected via 3 atoms to form a cyclic group containing 6 carbon atoms substituted with a hydroxy group. It is envisioned that these modifications can be performed either before or after formation of a cyclic phosphonate 1,3-propanediol ester. Various 1,3-cyclohexanediols can also be prepared using Diels-Alder reactions (*e.g.*, using a pyrone as the diene: *Tetrahedron Lett.* **1991,** *32,* 5295). 2-Hydroxymethylcyclohexanols and 2-hydroxymethylcyclopentanols are useful for the preparations of compounds of Formula I wherein R^{11} and R^{11} together are



wherein together V and Z are connected via 2 or 3 atoms to form a cyclic group containing 5 or 6 carbon atoms. 1,3-Cyclohexanediol derivatives are also prepared via other cycloaddition reaction methodologies. For example, cycloadducts from the cycloadditon reactions of a nitrile oxide and an olefin can be converted to a 2-ketoethanol derivative which can be further converted to a 1,3-propanediol (including1,3-cyclohexanediol, 2-hydroxymethylcyclohexanol and 2-hydroxymethylcyclopentanol) using known chemistry (*J. Am. Chem. Soc.* **1985**, *107*, 6023). Alternatively, precursors to 1,3-cyclohexanediol can be made from quinic acid (*Tetrahedron Lett.* **1991**, *32*, 547.)

EXPERIMENTAL

Example 1:

Compound 1: *N*-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-hydroxyphenoxy)] carbamoylphosphonic acid

Step a:

A mixture of 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)aniline (*J. Med. Chem.* **1995**, *38*, 695, 0.1 g, 0.35 mmol) and diphosgene (0.04 g, 0.19 mmol) in dioxane (3.0 mL) was heated at 60 °C for 3 h. The reaction mixture was cooled to room temperature and the solvent was removed under reduced pressure. To the residue was added a solution of diethyl phosphite (0.06 g, 0.42 mmol) in hexanes (1.0 mL with 3 drops of triethylamine) and the reaction mixture was heated under reflux for 3 h. The reaction mixture was cooled to room temperature and the solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:3) to afford the diethyl phosphonate as an oil (0.1 g, 64%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.44 (s, 1 H), 7.17 (s, 2 H), 6.10-6.60 (m, 3 H), 4.10 (m, 4 H), 3.58 (s, 3 H), 3.07 (m, 1 H), 1.92 (s, 3 H), 1.93 (s, 3 H), 1.22 (m, 6 H), 0.99 (m, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (3:1); R_f= 0.3.

Step b:

To a solution of diethyl *N*-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxy-phenoxy)] carbamoylphosphonate (0.1 g, 0.22 mmol) in CH_2Cl_2 (1.5 mL) at –78 °C was added bromotrimethylsilane (0.30 mL, 2.2 mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was dissolved in CH_2Cl_2 (2.0 mL) and the solution was cooled to -78 °C. Boron tribromide (1.3 mL, 1.3 mmol, 1.0 M in CH_2Cl_2) was added and the reaction mixture was stirred at room temperature for 16 h. The reaction mixture was poured into ice and extracted with ethyl acetate (20 mL). The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by preparative LC-MS to afford the title compound as a yellow solid (0.035 g, 42%): mp 67-70 °C; Anal. Calcd for ($C_{18}H_{22}NO_6P$ + 0.2 H_2O + 0.3 CH_3OH): C, 55.99; H, 6.06; N, 3.57. Found: C, 55.79; H, 6.21; N, 3.39.

Example 2

Compound 2: 1-amino-2-[3,5-diiodo-4-(4'-hydroxy-3'-iodophenoxy) phenyl]ethylphosphonic acid

Step a:

To a solution of 4-benzyloxyphenylacetyl chloride (4.0 g, 16.2 mmol) in THF (10.0 mL) at room temperature was slowly added triethyl phosphite (3.33 mL, 19.5 mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was treated with hexanes (20 mL) and the mixture was filtered. White solid was collected and air-dried. The solid was dissolved in pyridine (25.0 mL) and hydroxylamine hydrochloride (1.96 g, 28 mmol) was added. The reaction mixture was stirred at room temperature for 72 h and the solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (7:3) to afford diethyl 2-(4-benzyloxyphenyl)-1-(hydroxyimino)ethylphosphonate as a colorless oil (5.2 g, 85%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.18-7.38 (m, 7 H), 6.80 (d, J = 6.2 Hz, 2 H), 4.94 (s, 2 H), 3.80-4.10 (m, 4 H), 3.80 (s, 1 H), 3.76 (s, 1 H), 1.16 (t, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (2:3); R_f = 0.55.

Step b:

To a mixture of diethyl 2-(4-benzyloxyphenyl)-1-hydroxyiminoethylphosphonate (2.0 g, 5.3 mmol) and $NiCl_2$ (2.53 g, 10.6 mmol) in CH_3OH (40.0 mL) at room temperature was slowly added $NaBH_4$ (1.0 g, 26.4 mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was treated with 10% aqueous KOH (100 mL) and the mixture was extracted with ethyl ether (2x100 mL). The organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The residue was dissolved in THF (14.0 mL) and $(BOC)_2O$ (0.74 g, 3.4 mmol) was added. The reaction mixture was heated under reflux for 4 h and cooled to room temperature. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with 4% CH_3OH in CH_2Cl_2 to afford diethyl 2-(4-benzyloxyphenyl)-1-(*tert*-butoxycarbonylamino) ethylphosphonate as an oil (1.12 g, 46%): ^1H NMR (300 MHz, CD_3OD): δ 7.38 (m, 5 H), 7.13 (d, J = 8.4 Hz, 2 H), 6.88 (d, J = 8.4 Hz, 2 H), 4.88 (s, 2 H), 4.12 (m, 5 H), 3.08 (m, 1 H), 2.70 (m, 1 H), 1.34 (m, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = CH_3OH-CH_2Cl_2 (5:95); R_f = 0.45.

Step c:

A mixture of diethyl 2-(4-benzyloxyphenyl)-1-(*tert*-butoxycarbonylamino) ethylphosphonate (1.1 g, 2.4 mmol) and Pd-C (0.23 g, 10%) in CH_3OH (10 mL) was stirred under a H_2 atmosphere for 16 h and filtered through a Celite plug. The solvent was removed under reduced pressure and the residue was dissolved in $CHCl_3$ (15.0 mL). To the solution was added bis(pyridine)iodonium tetrafluoroborate (1.90 g, 5.1 mmol). The reaction mixture was stirred at room temperature for 1 h and the solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:1) to afford diethyl 1-(*tert*-butoxycarbonylamino)-2-(3,5-diiodo-4-hydroxyphenyl)ethylphosphonate as a yellow solid (1.30 g, 88%): ^1H NMR (300 MHz, CD_3OD): δ 7.67 (s, 2 H), 7.13 (d, J = 8.4 Hz, 1 H), 4.00-4.25 (m, 5 H), 3.00 (m, 1 H), 2.64 (m, 1 H), 1.38 (m, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = CH_3OH-CH_2Cl_2 (5:95); R_f = 0.70.

Step d:

To a mixture of diethyl 1-(*tert*-butoxycarbonylamino)-2-(3,5-diiodo-4-hydroxyphenyl)ethylphosphonate (0.6 g, 0.96 mmol), 4-(*tert*-butyldimethylsilyloxy) phenylboronic acid (0.73 g, 2.89 mmol), copper acetate (0.21 g, 1.16 mmol) and 4A molecular sieves (1.20 g) in CH_2Cl_2 (8.0 mL) was added a solution of pyridine (0.4 mL, 4.8 mmol) and TEA (0.7 mL, 4.8 mmol). The reaction mixture was stirred at room temperature for 48 h, filtered through a Celite plug and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:3) to afford diethyl 1-(*tert*-butoxycarbonylamino)-2-[4-(4'-(*tert*-butyldimethylsilyloxy)phenoxy)-3,5-diiodophenyl]ethylphosphonate as a white solid (0.48 g, 60%): ^{1}H NMR (300 MHz, CD_3OD): δ 7.64 (s, 2 H), 7.18 (d, J = 8.4 Hz, 1 H), 6.64 (d, J = 8.4 Hz, 1 H), 6.53 (d, J = 8.4 Hz, 1 H), 6.38 (d, J = 8.4 Hz, 1 H), 4.00 (m, 5 H), 2.90 (m, 1 H), 2.58 (m, 1 H), 1.20 (m, 6 H), 0.90 (m, 9 H), 0.03 (s, 3 H), 0.02 (s, 3 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (3:7); R_f = 0.60.

Step e:

To a mixture of diethyl 1-(*tert*-butoxycarbonylamino)-2-[4-(4-(*tert*-butyldimethylsilanyloxy)phenoxy)-3,5-diiodophenyl]ethylphosphonate (0.45 g, 0.54 mmol) in THF (6.0 mL) at 0 °C was added TBAF (0.81 mL, 0.81 mmol, 1.0 M in THF). The reaction mixture was stirred at room temperature for 20 min and the solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:1) to afford diethyl 1-(*tert*-butoxycarbonylamino)-2-[3,5-diiodo-4-(4'-hydroxyphenoxy)phenyl] ethylphosphonate as a white solid (0.24 g, 62%): ^{1}H NMR (300 MHz, CD_3OD): δ 7.74 (s, 2 H), 6.58 (d, J = 8.4 Hz, 2 H), 6.45 (d, J = 8.4 Hz, 2 H), 4.12 (m, 5 H), 3.08 (m, 1 H), 2.64 (m, 1 H), 1.32 (m, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (1:1); R_f = 0.40.

Step f:

A mixture of diethyl 1-(*tert*-butoxycarbonylamino)-2-[3,5-diiodo-4-(4'-hydroxyphenoxy) phenyl]ethylphosphonate (0.14g, 0.20 mmol) in 70% aqueous TFA (5.0 mL) was stirred at room temperature for 1 h and the solvent was removed under reduced pressure. The residue was dissolved in C_2H_5OH (4.0 mL) and cooled to 0 °C. To the solution was added 40% aqueous methylamine (0.80 mL) followed by a solution of

potassium iodide (0.16 g, 0.96 mmol) and iodine (0.06 g, 0.23 mmol) in H_2O (0.6 mL). The reaction mixture was stirred at 0 °C for 1 h, quenched with water and extracted with ethyl acetate (2x10 mL). The organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with 4% CH_3OH in CH_2Cl_2 to afford diethyl 1-amino-2-[3,5-diiodo-4-(4'-hydroxy-3'-iodo-phenoxy)phenyl]ethylphosphonate as a yellow solid (0.10 g, 69%): ^1H NMR (300 MHz, CD_3OD): δ 7.85 (s, 2 H), 7.00 (d, J = 5.2 Hz, 1 H), 6.74 (d, J = 8.4 Hz, 1 H), 6.64 (dd, J = 3.2, 8.4 Hz, 1 H), 4.18 (m, 5 H), 3.08 (m, 1 H), 2.78 (m, 1 H), 1.36 (m, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = CH_3OH-CH_2Cl_2 (5:95): R_f = 0.55.

Step g:

To a mixture of diethyl 1-amino-2-[3,5-diiodo-4-(4'-hydroxy-3'-iodo-phenoxy) phenyl]ethylphosphonate (0.05 g, 0.07 mmol) in CH_2Cl_2 (2.0 mL) at -78 °C was added bromotrimethylsilane (0.18 mL, 1.34 mmol). The reaction mixture was stirred at room temperature for 24 h and the solvent was removed under reduced pressure. The crude product was treated with CH_3CN-H_2O (5.0 mL, 9:1) and the solvent was removed under reduced pressure to afford 1-amino-2-[3,5-diiodo-4-(4'-hydroxy-3'-iodophenoxy) phenyl]ethylphosphonic acid as a yellow solid (0.044 g, 95%): mp 140 °C, dec; LC-MS m/z = 688 $[C_{14}H_{13}I_3NO_5P + H]^+$; Anal. Calcd for ($C_{14}H_{13}I_3NO_5P$ + 1.0 H_2O + 0.3 HBr): C, 23.06; H, 2.11; N, 1.92. Found: C, 22.74; H, 2.16; N, 1.67.

Example 3

Compound 3: 2-[3,5-diiodo-4-(4'-hydroxy-3'-iodophenoxy)phenyl]ethylphosphonic acid

Step a:

To a solution of tetraethyl methylenediphosphonate (1.6 g, 5.6 mmol) in THF (16.0 mL) at 0 °C was slowly added sodium hydride (0.14 g, 5.6 mmol). The reaction mixture was stirred at 0 °C for 30 min and a solution of 4-benzyloxybenzaldehyde (1.0 g, 4.7 mmol) in THF (4.0 mL) was added. The reaction mixture was stirred at 0 °C for 30 min, quenched with H_2O (30 mL) and extracted with ethyl acetate (30 mL). The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford the phosphonate as white solid (1.5 g). The solid was dissolved in CH_3OH (15.0 mL) and Pd-C (0.40 g) was added. The reaction mixture was

stirred under a H_2 atmosphere for 16 h, filtered through a Celite plug and concentrated under reduced pressure to afford diethyl 2-(4-hydroxyphenyl)ethylphosphonate as an oil (1.10 g, 91%): ^{1}H NMR (300 MHz, CD_3OD): δ 7.03 (d, J = 8.4 Hz, 2 H), 6.69 (d, J = 8.4 Hz, 2 H), 4.05 (m, 4 H), 2.77 (m, 2 H), 2.05 (m, 2 H), 1.30 (t, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (1:1); R_f = 0.5.

Step b:

To a solution of diethyl 2-(4-hydroxyphenyl)ethylphosphonate (0.5 g, 1.9 mmol) in CH_2Cl_2 (12.0 mL) at room temperature was added bis(pyridine)iodonium tetrafluoroborate (1.6 g, 4.3 mmol). The reaction mixture was stirred at room temperature for 1 h and the solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:1) to afford diethyl 2-(3,5-diiodo-4-hydroxyphenyl)ethylphosphonate as a white solid (0.92 g, 90%): ^{1}H NMR (300 MHz, CD_3OD): δ 7.62 (s, 2 H), 4.05 (m, 4 H), 2.77 (m, 2 H), 2.05 (m, 2 H), 1.29 (t, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (1:1); R_f = 0.57.

Step c:

Diethyl 2-[3,5-diiodo-4-(4'-hydroxyphenoxy)phenyl]ethylphosphonate was synthesized from diethyl 2-(3,5-diiodo-4-hydroxyphenyl)ethylphosphonate (0.5 g, 0.98 mmol) by following the procedure described in example 2, step d followed by example 2, step e: white solid (0.15 g, 25%)^{1}H NMR (300 MHz, CD_3OD): δ 7.81 (s, 2 H), 6.68 (d, J = 8.4 Hz, 2 H), 6.53 (d, J = 8.4 Hz, 2 H), 4.07 (m, 4 H), 2.84 (m, 2 H), 2.16 (m, 2 H), 1.32 (t, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (1:1); phenol: R_f = 0.35.

Step d:

To a solution of diethyl 2-[3,5-diiodo-4-(4'-hydroxyphenoxy)phenyl] ethylphosphonate (0.15 g, 0.25 mmol) in ethanol (5.0 mL) at 0 °C was slowly added a solution of potassium iodide (0.19 g, 0.75 mmol) and iodine (0.07 g, 0.3 mmol) in H_2O (0.5 mL). The reaction mixture was stirred at 0 °C for 1 h, quenched with H_2O (10.0 mL) and extracted with ethyl acetate (15.0 mL). The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with 2% CH_3OH in CH_2Cl_2 to afford diethyl 2-[3,5-diiodo-4-(4'-hydroxy-3'-iodophenoxy)phenyl]ethylphosphonate as a white

solid (0.10 g, 56%): ^{1}H NMR (300 MHz, CD_3OD): δ 7.83 (s, 2 H), 6.96 (d, J = 5.4 Hz, 1 H), 6.73 (d, J = 8.4 Hz, 2 H), 6.62 (dd, J = 4.2, 8.4 Hz, 1 H), 4.08 (m, 4 H), 2.88 (m, 2 H), 2.18 (m, 2 H), 1.32 (t, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = CH_3OH-CH_2Cl_2 (5:95); R_f = 0.50.

Step e:

To a solution of diethyl 2-[3,5-diiodo-4-(4'-hydroxy-3'-iodophenoxy)phenyl] ethylphosphonate (0.06 g, 0.08 mmol) in CH_2Cl_2 (1.5 mL) at 0 °C was slowly added bromotrimethylsilane (0.11 mL, 0.80 mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was treated with CH_3CN-H_2O (1:1, 5.0 mL) and the solvent was removed under reduced pressure to afford 2-[3,5-diiodo-4-(4'-hydroxy-3'-iodophenoxy)phenyl]ethylphosphonic acid as an off-white solid (0.05 g, 96%): mp 188 °C, dec; LC-MS m/z = 673 $[C_{14}H_{12}I_3O_5P + H]^+$; Anal. Calcd for ($C_{14}H_{12}I_3O_5P$ + 1.0 CH_3OH + 0.3 HBr): C, 24.45; H, 2.02; I, 53.45. Found: C, 24.79; H, 1.87; I, 53.36.

Example 4

Compound 4: 2-[3,5-diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy) phenyl]ethylphosphonic acid

Step a:

To a mixture of bis(4-methoxy-3-*iso*-propylphenyl)iodonium tetrafluoroborate (0.30 g, 0.59 mmol, N. Yokoyama *et al. J. Med. Chem.* **1995**, *38*, 695) and copper (0.05 g, 0.78 mmol) in CH_2Cl_2 (1.5 mL) at 0 °C was slowly added a solution of diethyl 2-(3,5-diiodo-4-hydroxyphenyl)ethylphosphonate (0.2 g, 0.39 mmol) and TEA (0.10 mL, 0.66 mmol) in CH_2Cl_2 (0.6 mL). The reaction mixture was stirred at room temperature for 96 h, filtered through a Celite plug and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (2:3) to afford diethyl 2-[3,5-diiodo-4-(4'-methoxy-3'-*iso*-propylphenoxy)phenyl]ethylphosphonate as an off-white solid (0.25 g, 97%): ^{1}H NMR (300 MHz, CD_3OD): δ 7.82 (s, 2 H), 6.78 (d, J = 9.0 Hz, 1 H), 6.68 (d, J = 3.0 Hz, 1 H), 4.07 (m, 4 H), 3.30 (m, 1 H), 2.85 (m, 2 H), 2.18 (m, 2 H), 1.30 (t, J = 6.9 Hz, 6 H), 1.15 (d, J = 7.2 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (3:7); R_f = 0.64.

Step b:

To a solution of diethyl 2-[3,5-diiodo-4-(4'-methoxy-3'-*iso*-propylphenoxy) phenyl]ethylphosphonate (0.25 g, 0.38 mmol) in CH_2Cl_2 (3.0 mL) at 0 °C was slowly added bromotrimethylsilane (0.60 mL, 3.8 mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was dissolved in CH_2Cl_2 (3.0mL) and cooled to -78 °C. Boron tribromide (1.80 mL, 1.80 mmol, 1.0 M CH_2Cl_2) was slowly added and the reaction mixture was stirred at room temperature for 16 h. The reaction mixture was poured into ice (50 g) and extracted with ethyl acetate (20 mL). The organic layer was dried over $MgSO_4$, filtered and concentrated to afford 2-[3,5-diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy) phenyl]ethylphosphonic acid as an off-white solid (0.20 g, 91%): mp 184-186 °C; LC-MS m/z = 589 $[C_{17}H_{19}I_2O_5P + H]^+$; Anal. Calcd for $C_{17}H_{19}I_2O_5P$: C, 34.72; H, 3.26. Found: C, 34.75; H, 3.12.

Example 5

Compound 5: 3,5-diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzylphosphonic acid

Step a:

A mixture of 4-benzyloxybenzyl bromide (Chow *et al.*, *J. Org. Chem.* **1997**, *62*, 5116-27) (1.0 g, 4.4 mmol) and triethyl phosphite (1.0 mL, 5.8 mmol) in DMF (2.8 mL) was heated at 155 °C for 4 h. The reaction mixture was cooled to room temperature, quenched with H_2O (10 mL) and extracted with ethyl acetate (20 mL). The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (2:3) to afford the phosphonate as an oil (1.3 g). The phosphonate was dissolved in CH_3OH (12.0 mL) and Pd-C (10%, 0.33 g) was added. The reaction mixture was stirred under a H_2 atmosphere for 16 h, filtered through a Celite plug and concentrated under reduced pressure to afford diethyl 4-hydroxybenzylphosphonate as an oil (0.9 g, 84%): ^{1}H NMR (300 MHz, CD_3OD): δ 7.12 (d, J = 8.4 Hz, 2 H), 6.73 (d, J = 8.4 Hz, 2 H), 4.05 (m, 4 H), 3.16 (s, 1 H), 3.09 (s, 1 H), 1.26 (t, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (1:1); R_f = 0.5.

Step b:

Diethyl 3,5-diiodo-4-hydroxybenzylphosphonate (0.85 g, 85%) was synthesized from diethyl 4-hydroxybenzylphosphonate (0.5 g, 2.1 mmol) by following the procedure

described in example 3, step b: ^{1}H NMR (300 MHz, CD_3OD): δ 7.67 (d, J = 2.7 Hz, 2 H), 4.08 (m, 4 H), 3.15 (s, 1 H), 3.08 (s, 1 H), 1.28 (t, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (2:3); R_f = 0.6.

Step c:

Diethyl 3,5-diiodo-4-(4'-methoxy-3'-*iso*-propylphenoxy)benzylphosphonate (0.22 g, 88%) was synthesized from diethyl 3,5-diiodo-4-hydroxybenzylphosphonate (0.2 g, 0.4 mmol) by following the procedure described in example 4, step a: ^{1}H NMR (300 MHz, CD_3OD): δ 7.87 (d, J = 2.7 Hz, 2 H), 6.80 (d, J = 8.7 Hz, 1 H), 6.62 (d, J = 2.0 Hz, 1 H) 6.42 (dd, J = 3.3, 8.7 Hz, 1 H), 4.08 (m, 4 H), 3.78 (s, 3 H), 3.25 (m, 3 H), 1.32 (t, J = 6.9 Hz, 6 H), 1.14 (d, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (2:3); R_f = 0.6.

Step d:

3,5-Diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzylphosphonic acid (0.18 g, 92%) was synthesized from diethyl 3,5-diiodo-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzylphosphonate (0.22 g, 0.34 mmol) by following the procedure described in example 4, step b: mp > 220 °C; LC-MS m/z = 575 [$C_{16}H_{17}I_2O_4P$ + H]$^+$; Anal. Calcd for ($C_{16}H_{17}I_2O_5P$+0.3 H_2O+0.5CH_3OH): C, 33.28; H, 3.32; I, 42.62. Found: C, 33.49; H, 3.23; I, 42.51.

Example 6

Compound 6: 3,5-diiodo-4-(4'-hydroxy-3'-iodophenoxy)benzylphosphonic acid

Step a:

Diethyl 3,5-diiodo-4-(4'-hydroxyphenoxy)benzylphosphonate (0.11 g, 17%) was obtained from diethyl 3,5-diiodo-4-hydroxybenzylphosphonate (0.55 g, 1.1 mmol) by following the procedure described in example 3, step c: ^{1}H NMR (300 MHz, CD_3OD): δ 7.87 (d, J = 2.7 Hz, 2 H), 6.70 (d, J = 8.7 Hz, 2 H), 6.54 (d, J = 2.0 Hz, 2 H) 4.10 (m, 4 H), 3.30 (s, 1 H), 3.22 (s, 1 H), 1.31 (m, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (1:1); R_f = 0.4.

Step b:

Diethyl 3,5-diiodo-4-(4'-hydroxy-3'-iodophenoxy)benzylphosphonate (0.08 g, 63%) was obtained from diethyl3,5-diiodo-4-(4'-hydroxyphenoxy)benzylphosphonate (0.1 g, 0.1 mmol) by following the procedure described in example 3, step d: ^{1}H NMR (300 MHz, CD_3OD): δ 7.87 (d, J = 2.4 Hz, 2 H), 6.92 (d, J = 6.4 Hz, 1 H), 6.74 (d, J =

8.7Hz, 1 H), 6.62 (dd, $J = 2.4, 8.7$ Hz, 1 H), 4.10 (m, 4 H), 3.30 (s, 1 H), 3.22 (s, 1 H), 1.31 (t, $J = 6.9$ Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = CH_3OH-CH_2Cl_2 (2:98); $R_f = 0.6$.

Step c:

3,5-Diiodo-4-(4'-hydroxy-3'-iodophenoxy)benzylphosphonic acid (0.06 g, 90%) was obtained from diethyl 4-(4'-hydroxy-3'-iodophenoxy)-3,5-diiodobenzylphosphonate (0.08g, 0.1 mmol) by following the procedure described in example 3, step e: mp 168 °C, dec; LC-MS *m/z* = 659 $[C_{13}H_{10}I_3O_5P + H]^+$; Anal. Calcd for ($C_{13}H_{10}I_3O_5P$+1.6$H_2O$+ 0.5$CH_3OH$): C, 23.07; H, 2.18; I, 54.17. Found: C, 22.71; H, 1.80; I, 53.82.

Example 7

Compound 7: [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenoxy]methylphosphonic acid

Step a:

To a stirring solution of NaH (0.855 g, 21.4 mmol) in DMF (40.0 mL) at 0 °C was added a solution of 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol (5.60 g, 17.8 mmol), (G. Chiellini *et al. Bioorg. Med. Chem. Lett.* **2000**, *10*, 2607) in DMF (7.0 mL). The reaction mixture was stirred at room temperature for 1 h and cooled to 0° C. A solution of diethyl tosyloxymethylphosphonate (6.89 g, 21.4 mmol) in DMF (7.0 mL) was added. The reaction mixture was stirred at room temperature for 16 h, quenched with CH_3OH followed by dilution with water (100 mL) and extracted with ether (100 mLx2). The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:3) to afford diethyl [3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonate as a colorless oil (5.32 g, 64%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.94 (d, $J = 3.0$ Hz, 1 H), 6.87 (d, $J = 9.0$ Hz, 1 H), 6.73 (s, 2 H), 6.58 (m, 1 H), 5.14 (s, 2 H), 4.36 (d, $J = 9.0$ Hz, 2 H), 4.10 (m, 4 H), 3.85 (s, 2 H), 3.36 (s, 3 H), 3.21 (m, 1 H), 2.17 (d, $J = 6.0$ Hz, 6 H), 1.25 (m, 6 H), 1.12-1.10 (d, $J = 6.0$ Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (1:1); $R_f = 0.62$.

Step b:

To a solution of diethyl 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenoxymethylphosphonate (5.32 g, 11.45 mmol) in dichloromethane (60.0 mL)

at 0 °C was added bromotrimethylsilane (22.67 mL, 171.7 mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was treated with acetonitrile-water (1:1, 50 mL) and the solvent was removed under reduced pressure. The residue was treated with toluene and sonicated for 10 min. The mixture was filtered and washed with hexanes to afford [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid as a pink solid (4.00 g, 95%): mp 55-58 °C; LC-MS *m/z* = 365 [$C_{19}H_{25}O_5P$ + H]$^+$; Anal. Calcd for ($C_{19}H_{25}O_5P$ + 0.5 H_20 + 0.2 CH_3OH): C, 60.72; H, 7.11. Found: C, 60.72, H, 7.18.

Using the appropriate starting material, compounds 7-1 to 7-21 were prepared in an analogous manner to that described for the synthesis of compound 7.

Compound 7-1: [3,5-dimethyl-4-(4'-hydroxy-3'-phenylbenzyl) phenoxy]methylphosphonic acid

Intermediate 3,5-dimethyl-4-(4'-methoxymethoxy-3'-phenylbenzyl)phenol was prepared from 2-phenylphenol according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7.

^{1}H NMR (300 MHz, DMSO-d_6): δ 9.29 (s, 1 H), 6.60-7.60 (m, 8 H), 4.02 (d, J = 15 Hz, 2 H), 2.18 (s, 2 H); LC-MS *m/z* = 399 [$C_{29}H_{41}O_{11}P$ + H]$^+$; Anal. Calcd for ($C_{29}H_{41}O_{11}P$ + 1.7 H_2O + 0.4 CH_3OH): C, 60.89; H, 6.39. Found: C, 60.53; H, 6.19.

Compound 7-2: [3,5-dimethoxy-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid

Intermediate 3,5-dimethoxy-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenol was prepared from 2,6-dimethoxy-4-hydroxybenzaldehyde according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7.

^{1}H NMR (300 MHz, DMSO-d_6): δ 8.86 (s, 1 H), 6.96 (d, J = 1.8 Hz, 1 H), 6.64 (dd, J = 1.8 Hz, J = 8.4 Hz, 1 H), 6.54 (d, J = 8.4 Hz, 1 H), 6.27 (s, 2 H), 4.07 (d, J = 10.2 Hz, 2 H), 3.74 (s, 6 H), 3.64 (s, 2 H), 3.08 (m, 1 H), 1.08 (d, J = 6.9 Hz, 6 H); LC-MS *m/z* =

397 $[C_{19}H_{25}O_7P + H]^+$; Anal Calcd for ($C_{19}H_{25}O_7P$ + 0.4 $CH_3CO_2C_2H_5$ + 0.9 H_2O): C, 55.25; H, 6.75. Found: C, 55.22; H, 7.13.

Compound 7-3: [3,5-dimethyl-4-(3'-*sec*-butyl-4'-hydroxybenzyl)phenoxy]methylphosphonic acid

Intermediate 3,5-dimethyl-4-(3'-*sec*-butyl-4'-methoxymethoxybenzyl)phenol was prepared from commercially available 2-*sec*-butylphenol according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7.

^{1}H NMR (200 MHz, DMSO-d_6): δ 8.92 (s, 1 H), 6.77 (s, 1 H), 6.68 (s, *2* H), 6.61 (d, J = 8.6 Hz, 1 H), 6.47 (d, J = 8.6 Hz, 1 H), 4.02 (d, J = 10.2 Hz, 2 H), 3.78 (s, 2 H), 2.90 (m, 1 H), 1.45 (q, J = 6.6 Hz, 2 H), 1.05 (d, J = 7.0 Hz, 3 H), 0.74 (t, J = 7.0 Hz, 3 H); LC-MS m/z = 379 $[C_{20}H_{27}O_5P + H]^+$; Anal Calcd for ($C_{20}H_{27}O_5P$ + 0.7 H_2O): C, 61.43; H, 7.32. Found: C, 61.22; H, 7.55.

Compound 7-4: [3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxybenzyl)phenoxy]methylphosphonic acid

Intermediate 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxybenzyl)phenol was prepared from 2-*iso*-propylanisole according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7.

^{1}H NMR (300 MHz, DMSO-d_6): δ 6.99 (d, J = 2.1 Hz, 1 H), 6.88 (d, J = 8.4 Hz, 1 H), 6.76 (s, 2 H), 6.66 (m, 1 H), 4.09 (d, J = 10.2 Hz, 2 H), 3.91 (s, 2 H), 3.78 (s, 3 H), 3.23 (m, 1 H), 2.29 (s, 6 H), 1.16 (d, J = 7.2 Hz, 6 H); LC-MS m/z = 378 $[C_{20}H_{27}O_5P + H]^-$; Anal. Calcd for ($C_{20}H_{27}O_5P$ + 0.3 H_2O): C, 62.59; H, 7.25. Found: C, 62.37; H, 7.40.

Compound 7-5: [3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid

Intermediate 3,5-dichloro-4-(3'-*sec*-butyl-4'-methoxymethoxybenzyl)phenol was prepared from 2,6-dichloro-4-benzyloxybenzaldehyde (*Organic Letters* **2002**, *4*, 2833) according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7.

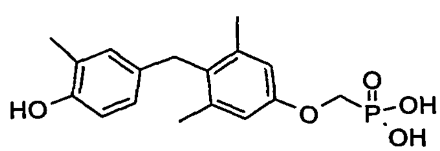
mp.: 118 -120 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 7.01 (s, 2 H), 6.87 (d, J = 1.8 Hz, 1 H), 6.60 (dd, J = 3.0, 8.4 Hz, 1 H), 6.47 (d, J = 8.4 Hz, 1 H), 4.12 (d, J = 9.9 Hz, 2 H), 4.02 (s, 2 H), 3.20 - 3.10 (m, 1 H), 1.03 (d, J = 6.9 Hz, 6 H); LC-MS m/z = 405 $[C_{17}H_{19}Cl_2O_5P]^+$; Anal Calcd for: $(C_{17}H_{19}Cl_2O_5P)$: C, 50.39, H, 4.73 Cl: 17.60. Found: C, 50.33, H, 5.03; Cl, 16.09.

<u>**Compound 7-6:** difluoro-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid</u>

Intermediate 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenol was prepared from 2-*iso*-propylphenol according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7 using diethyl bromodifluoromethylphosphonate.

^{1}H NMR (300 MHz, DMSO-d_6): δ 9.02 (s, 1 H), 6.88 (m, 3 H), 6.65 (m, 1 H), 4.46 (m, 1 H), 3.84 (s, 3 H), 3.12 (s, 2 H), 3.12 (m, 1 H), 2.19 (s, 6 H), 1.12 (d, J = 6.0 Hz, 6 H); HPLC conditions: Column = 3 Chromolith SpeedRODs RP-18e, 100×4.6 mm; Mobile phase = Solvent A (Acetonitrile) = HPLC grade acetonitrile; Solvent B (buffer) = 20 mM ammonium phosphate buffer (pH 6.1, 0.018 M $NH_4H_2PO_4$/0.002 M $(NH_4)_2HPO_4$) with 5% acetonitrile. Flow rate = 4 mL/min; UV@ 255 nm. Retention time in minutes (rt = 5.68, 95% purity).

<u>**Compound 7-7:** [3,5-dimethyl-4-[4'-hydroxy-3'-methylbenzyl]phenoxy]methylphosphonic acid</u>



Intermediate 3,5-dimethyl-4-[3'-methyl-4'-methoxymethoxybenzyl]phenol was prepared from 4-bromo-2-methyl-phenol according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7

mp>230 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.99(s, 1H), 6.68 – 6.525(m, 5H), 6.71(s, 2H), 4.03(d, 2H, J = 7.5 Hz), 3.77(s, 2H), 2.15(s, 6H), 2.02(s, 3H); LC- MS m/z = 335 [$C_{17}H_{21}O_5P$ – H]; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = isopropyl alcohol/water/ammonium hydroxide [7:2:1]; Rf = 0.23; Anal. Calcd for ($C_{17}H_{21}O_5P$ + 0.6 H_2O): C, 58.82; H, 6.45; Found: C, 58.73, H, 6.73.

Compound 7-8: [3,5-dimethyl-4-[3'-ethyl-4'-hydroxybenzyl]phenoxy]methylphosphonic acid

Intermediate 3,5-dimethyl-4-[3'-ethyl-4'-methoxymethoxybenzyl]phenol was prepared from 4-bromo-2-ethyl-phenol according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000,** *10,* 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7

^{1}H NMR (300 MHz, DMSO-d_6): δ 8.96(s, 1H), 6.72 – 6.49(m, 5H), 4.03(d, 2H, J = 10.2 Hz), 3.78(s, 2H), 2.48(q, 2H, J = 8.1 Hz), 2.16(s, 6H), 1.06(t, 3H, J = 7.5 Hz); LC- MS m/z = 349 [$C_{18}H_{23}O_5P$ – H]; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = Isopropyl alcohol/ammonium hydroxide/water [7:2:1]; Rf = 0.20; Anal. Calcd for ($C_{17}H_{21}O_5P$ +1.3 H_2O + 0.3 CH_2Cl_2): C, 55.30; H, 6.59; Found: C, 55.36, H, 6.66.

Compound 7-9: [3,5-dimethyl-4-[3'-(1-ethylpropyl)-4'-hydroxybenzyl]phenoxy]methylphosphonic acid

Intermediate 3,5-dimethyl-4-[3'-(1-ethylpropyl)-4'-methoxymethoxybenzyl]phenol was prepared from 2-(1-ethylpropyl)phenol (*J. Chem. Soc. Perkins Trans. 2,* **1985,** 165) according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000,** *10,* 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7

mp: 60-64 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.84 (s, 1 H), 6.72 (s, 1 H), 6.67 (s, 2 H), 6.60 (m, 1 H), 6.46 (m, 1 H), 4.04 (d, J = 9.0 Hz, 2 H), 3.78 (s, 2 H), 2.74 (m, 1 H), 2.15 (s, 6 H), 1.49 (m, 4 H), 0.68 (m, 6 H); LC-MS m/z = 393 [$C_{21}H_{29}O_5P$ + H]$^+$; Anal. Calcd for ($C_{21}H_{29}O_5P$ + 0.5 H_2O + 0.2 $CH_3CO_2CH_2CH_3$): C, 62.48; H, 7.60. Found: C, 62.22; H, 7.83.

Compound 7-10: [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propyl-5'-methylbenzyl)phenoxy]methylphosphonic Acid

Intermediate 3,5-dimethyl-4-(3'-*iso*-propyl-5'-methyl-4'-methoxymethoxybenzyl)phenol was prepared from 2-*iso*-propyl-6-methylphenol (*J. Med. Chem.* **1980**, *12*, 1350) according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7

mp: 65-68 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 6.75 (s, 2 H), 6.69 (d, J = 2.1 Hz, 1 H), 6.49 (d, J = 2.1 Hz, 1 H), 4.22 (d, J = 10.2 Hz, 2 H), 3.89 (s, 2 H), 3.27 (m, 1 H), 2.23 (s, 6 H), 2.14 (s, 3 H), 1.15 (d, J = 7.2 Hz, 6 H); LC-MS m/z = 377 $[C_{20}H_{27}O_5P - H]^+$; Anal. Calcd for ($C_{20}H_{27}O_5P$ + 1.0 H_2O): C, 60.60; H, 6.37. Found: C, 60.70; H, 7.75.

Compound 7-11: [3,5-dimethyl-4-(5'-fluoro-4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid

Step a:

To a mixture of 4-bromo-2-fluoroanisole (2.0 g, 9.70 mmol) and 2-propanol (1.2 g, 19.4 mmol) at room temperature was added 80% H_2SO_4 (10.0 mL). The reaction mixture was heated at 80 °C for 12 h, cooled to room temperature, quenched with ice (50 g) and extracted with ether (20 mLx2). The combined organic extracts were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with 5% ethyl acetate in hexanes to afford 4-bromo-6-fluoro-2-*iso*-propylanisole (0.92 g, 38 %): ^{1}H NMR (300 MHz, CD_3OD): δ 7.36 (d, J = 10.5 Hz, 1 H), 7.22 (d, J = 10.5 Hz , 1 H), 3.91 (s, 3 H), 3.24 (m, 1 H), 1.26 (d, J = 6.6 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (5:95); R_f = 0.50.

Step b:

To a solution of 4-bromo-6-fluoro-2-*iso*-propylanisole (0.92 g, 3.70 mmol) in CH_2Cl_2 (10.0 mL) at –78 °C was added BBr_3 (5.5 mL, 5.5 mmol, 1.0 M in CH_2Cl_2). After 5 min, the reaction mixture was stirred at room temperature for 16 h, poured into ice (50 g) and extracted with ethyl acetate (20.0 mL). The organic layer was separated, dried over $MgSO_4$ and filtered. The solvent was removed under reduced pressure to afford 4-bromo-6-fluoro-2-*iso*-propylphenol (0.90 g, 100%) as a dark oil, which was used for the next step without further purification: ^{1}H NMR (300 MHz, CD_3OD): δ 7.26

(d, J = 10.5 Hz, 1 H), 6.92 (d, J = 10.5 Hz , 1 H), 3.30 (m, 1 H), 1.23 (d, J = 6.6 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); R_f = 0.40.

Intermediate 3,5-dimethyl-4-(5'-fluoro-3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenol was prepared from 4-bromo-6-fluoro-2-*iso*-propylphenol according to the procedure described in G. Chiellini et al. *Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7.

mp: 166-168 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 6.89 (d, J = 9.0 Hz, 1 H), 6.80 (s, 2 H), 6.03 (d, J = 9.0 Hz,1 H), 4.25 (d, J = 8.4 Hz, 2 H), 3.91 (s, 2 H), 3.34 (m, 1 H), 2.18 (s, 6 H), 1.30 (d, J = 6.9 Hz, 6 H); LC-MS m/z = 383 $[C_{19}H_{24}FO_5P + H]^+$; Anal Calcd for ($C_{19}H_{24}FO_5P$ + 0.6 H_2O): C, 58.04; H, 6.46. Found: C, 57.88; H, 6.46.

<u>**Compound 7-12**: [4-(4'-acetylamino-3'-*iso*-propylbenzyl)-3,5-dimethyl phenoxy]methylphosphonic acid</u>

Step a:

To a cooled solution of 2-*iso*-propyl aniline (714 mg, 5.28 mmol) in dichloromethane (20 mL) at –50 °C in a dry ice/acetone bath was added a solution of bromine (269 μl, 5.28 mmol) in dichloromethane (5 mL) over 20 min. After completion of the addition, the reaction mixture was stirred for an additional hour. Purification by column chromatography (silica gel, hexane/ethyl acetate) gave 4-bromo-2-*iso*-propyl-phenylamine as a brown oil (1.53 g, 57%); ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.01(m, 2H), 6.55(d, 1H, J = 13 Hz), 5.05(bs, 2H), 2.92(m, 1H), 1.11(d, 6H, J = 7 Hz); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = Hexane/ethyl acetate [10:1]; Rf = 0.11

Step b:

A solution of 4-bromo-2-*iso*-propyl-phenylamine (780 mg, 3.64 mmol) in acetic anhydride (4 mL) was stirred at room temperature over night. The reaction was poured into water and the resulting white precipitate was filtered off and dried under vacuum to give *N*-(4-bromo-2-*iso*-propyl-phenyl)-acetamide as a light pink solid (0.770 g, 83%); ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.39(s, 1H), 7.43(d, 1H, J = 2.4 Hz), 3.16(m, 1H), 2.04(s, 3H), 1.13(d, 6H, J = 7 Hz); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = dichloromethane; Rf = 0.21

Intermediate 3,5-dimethyl-4-(5'-fluoro-3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenol was prepared from *N*-(4-bromo-2-*iso*-propyl-phenyl)-acetamide according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7: mp>230 °C; LC- MS m/z = 404 [$C_{21}H_{28}NO_5P$ – H]; 1H NMR (300 MHz, DMSO-d_6): δ 9.23(s, 1H), 7.03(m, 2H), 6.71(s, 2H), 6.60(d, 1H, J = 9.3 Hz), 4.04(d, 2H, J = 9.3 Hz), 3.91(s, 2H), 2.17(s, 6H), 2.00(s, 3H), 1.06(d, 6H, J = 6.9 Hz); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = isopropyl alcohol/water/ammonium hydroxide [7:2:1]; Rf = 0.26; Anal. Calcd for ($C_{21}H_{28}NO_5P$ + 0.4 H_2O): C, 61.13; H, 7.03; N, 3.39 Found: C, 61.36, H, 7.22, N, 3.03.

Compound 7-13: [4-(3'-*iso*-propyl-4'-methanesulfonylaminobenzyl)-3,5-dimethyl phenoxy]methylphosphonic acid

Step a:

Intermediate *N*-[4-(4'-hydroxy-2',6'-dimethyl-benzyl)-2-*iso*-propyl-phenyl]-acetamide from the synthesis of compound 7-12 (320 mg, 0.68 mmol) was combined with HCl (10 mL) and water (2 mL) in a round bottom flask and heated at reflux over night. The solvent was removed under reduced pressure and the resulting solid was dissolved in a mixture of ethyl acetate (50 mL) and water (2 mL). The organic layer was removed and dried over sodium sulfate, filtered and concentrated under reduced pressure to give 4-(4'-amino-3'-*iso*-propylbenzyl)-3,5-dimethylphenol as a white powder (0.179 g, 98%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.934(s, 1H), 6.73(d, 1H, J = 1.8 Hz), 6.43(m, 5H), 4.58(bs, 2H), 3.69(s, 2H), 2.92(m, 1H), 2.10(s, 6H), 1.07(d, 6H, J = 6.6 Hz); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = Ethyl acetate; Rf = 0.69.

Step b:

To a solution of 4-(4'-amino-3'-*iso*-propylbenzyl)-3,5-dimethylphenol (80 mg, 0.30 mmol) in DMF (3 mL) was added sodium hydride (8.5 mg, 0.36 mmol) and the reaction was stirred for 10 min. at room temperature. Trifluoromethanesulfonic acid diethoxyphosphorylmethyl ester was added and the reaction was stirred over night. An aqueous saturated solution of ammonium chloride (3 mL) was added and the resulting mixture was added to ethyl acetate (50 mL) and water (10 mL). The aqueous layer was removed and the ethyl acetate layer was washed 5 x with 10 mL water and 1 x with 10

mL brine. The ethyl acetate was dried over sodium sulfate, filtered and concentrated. The residue was purified by prep plate TLC using a 2000 μm silica gel plate eluted with ethyl acetate/ dichloromethane [3:1] to give diethyl [4-(4'-amino-3'-*iso*-propylbenzyl)-3,5-dimethylphenoxy]methylphosphonate (0.061 g, 49%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.74(d, 1H, J = 1.8 Hz), 6.72(s, 2H), 6.45(d, 1H, J = 14.4 Hz), 6.36(dd, 1H, J = 2 Hz, J = 7.5 Hz), 4.60(s, 2H), 4.35(d, 2H, J = 9.6 Hz), 4.11(m, 4H), 3.75(s, 2H), 2.90(m, 1H), 2.17(s, 6H), 1.25(t, 6H, J = 7 Hz), 1.07(d, 6H, J = 7.2 Hz); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = Ethyl acetate/Dichloromethane [1:1]; Rf = 0.54.

Step c:

To a solution consisting of diethyl [4-(4'-amino-3'-*iso*-propylbenzyl)-3,5-dimethylphenoxy]methylphosphonate (43.6 mg, 0.104 mmol), in dichloromethane (2 mL) was added methane sulfonyl chloride (1 eq, 8 μl), and pyridine (1 eq, 8.4 μl). The reaction was stirred overnight at room temperature under an N_2 atmosphere (balloon). The solvent was removed under reduced pressure and the resulting residue was dissolved in ethyl acetate (25 mL) and washed 2 x with water (10 mL), 1x with 1N HCl (10 mL), and 1 x with brine (10 mL). The ethyl acetate was dried over sodium sulfate filtered and concentrated under reduced pressure giving pure diethyl [4-(3'-*iso*-propyl-4'-methanesulfonylaminobenzyl)-3,5-dimethylphenoxy]methylphosphonate (0.047 g, 97%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.94(s, 1H), 7.08(m, 2H), 6.76(s, 2H), 6.68(dd, 1H, J = 2.1 Hz, J = 8.7 Hz), 4.36(d, 2H, J = 10.2 Hz), 4.11(m, 4H), 3.39(m, 1H), 2.94(s, 3H), 2.23(s, 6H), 1.25(m, 6H), 1.08(d, 6H, J = 7 Hz); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = Ethyl acetate/Dichloromethane [1:1]; Rf = 0.36.

Step d:

To a solution consisting of diethyl [4-(3'-*iso*-propyl-4'-methanesulfonylaminobenzyl)-3,5-dimethylphenoxy]methylphosphonate (43.8 mg, 0.09 mmol) and dichloromethane (2 mL) was added HMDS (191 μl, 0.9 mmol) and TMSBr (191 μl, 0.9 mmol). The reaction was stirred over night at room temperature. The solvent was removed under reduced pressure and the resulting residue was co-evaporated 3 x with 2 mL dichloromethane. The resulting residue was taken up in 1N NaOH (2 mL) and washed 2 x with dichloromethane. The residual dichloromethane was removed under reduced pressure and the resulting aqueous layer was acidified with concentrated HCl. The resulting precipitate was filtered off and dried under vacuum to give the title

compound as a light brown powder (0.022 g, 55%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.93 (s, 1 H), 7.10 (m, 2 H), 6.67 (m, 3 H), 4.02 (d, 2 H, J = 10 Hz), 3.91(s, 2H), 2.93(s, 3H), 2.16(s, 6H), 1.08(d, 6H, J = 7 Hz); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = Isopropyl alcohol/water/ammonium hydroxide [7:2:1]; R_f= 0.36; Anal. Calcd for ($C_{20}H_{28}O_6PS$ + 0.9 H_2O): C, 52.48; H, 3.56; N,3.06. Found: C, 52.49, H, 6.56, N, 3.23.

Compound 7-14: [3,5-dichloro-4-(5'-bromo-4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid

Step a:

To a mixture of diethyl [3,5- dichloro-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenoxy]methylphosphonate (0.25 g, 0.49 mmol, intermediate for the synthesis of compound 7-5) in methanol (3.0 mL) at 0 °C was added 2 N HCl (1.0 mL). The reaction mixture was stirred at room temperature for 24 h, quenched with water (10.0 mL) and extracted with ethyl acetate (10 .0 mL). The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with 30% acetone in hexanes to afford diethyl [3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonate (0.17 g, 74%) as a colorless oil: ^{1}H NMR (300 MHz, CD_3OD): δ 7.18 (s, 2 H), 7.00 (d, J = 2.4 Hz, 1 H), 6.75 (dd, J = 8.1, 2.4 Hz, 1 H), 6.62 (d, J = 8.1 Hz, 1 H), 4.48 (d, J = 10.5 Hz, 2 H), 4.25 (m, 4 H), 4.17 (s, 2 H), 3.25 (m, 1 H), 1.38 (t, J = 7.2 Hz, 6 H), 1.18 (d, J = 6.6 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (2:3); R_f = 0.70.

Step b:

To a mixture of diethyl [3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonate (0.16 g, 0.35 mmol) in CH_2Cl_2 (3.0 mL) at 0 °C was added tetrabutylammonium tribromide (0.18 g, 0.38 mmol). The reaction mixture was stirred at room temperature for 4 h and the solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with 30% acetone in hexanes to afford diethyl [3,5-dichloro-4-(5'-bromo-4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonate (0.12 g, 64%) as yellow oil: ^{1}H NMR (300 MHz, CD_3OD): δ 7.18 (s, 2 H), 7.02 (s, 2 H), 4.50 (d, J = 10.5 Hz, 2 H), 4.25 (m, 4 H), 4.18 (s, 2 H), 3.25 (m, 1 H), 1.38 (t, J = 7.2 Hz, 6 H), 1.18 (d, J = 6.6 Hz,

6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (2:3); R_f = 0.80.

The title compound was prepared by the procedure described for the synthesis of compound 7, step b: mp: 188-190 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 7.18 (s, 2 H), 7.03 (s, 2 H), 4.32 (d, J = 10.2 Hz, 1 H), 4.18 (s, 2 H), 3.20-3.40 (m, 1 H), 1.19 (d, J = 7.2 Hz, 6 H); LC-MS m/z = 483 [$C_{20}H_{27}O_5P$ - H]$^+$; Anal. Calcd for ($C_{17}H_{18}BrCl_2O_5P$ + 0.4 H_2O): C, 41.56; H, 3.86. Found: C, 41.44; H, 4.15.

Compound 7-15: [3,5-Dimethyl-4-[3'-ethoxy-4'-hydroxybenzyl]phenoxy]methylphosphonic acid

Intermediate 3,5-dimethyl-4-[3'-ethoxy-4'-methoxymethoxybenzyl]phenol was prepared from 4-bromo-2-ethoxy-phenol according to the procedure described in G. Chiellini et al. *Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7: ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.62 (s, 1 H), 6.71 (s, 2 H), 6.65 (d, J = 8.1 Hz, 1 H), 6.59 (d, J = 1.5 Hz, 1 H), 6.27 (dd, J = 1.5, 8.1 Hz, 1 H), 4.04 (d, J = 10.2 Hz, 2 H), 3.93 (q, J = 6.9 Hz, 2 H), 3.82 (s, 2 H), 2.16 (s, 6 H), 1.29 (t, J = 6.9 Hz, 3 H); mp: shrinks at 145 °C; LC-MS m/z = 367 [$C_{18}H_{23}O_6P$ + H]$^+$; Anal Calcd for ($C_{18}H_{23}O_6P$ + 0.2MeOH + 0.4H_2O): C, 57.53; H, 6.53. Found: C, 57.39; H, 6.23.

Compound 7-16: [3,5-Dimethyl-4-(4'-hydroxy-3'-*iso*-propyl-2'-methylbenzyl)phenoxy]methylphosphonic Acid

Step a:

To a solution of ethyl 2-methoxy-6-methylbenzoate (1.0 g, 5.1 mmol) in THF (15.0 mL) at –78 °C was added methylmagnesium bromide (3.78 mL, 11.32 mmol). After 5 min, the reaction mixture was allowed to warm to room temperature and stirred for 4 h. The mixture was cooled to 0 °C, quenched with 1.0 M HCl and extracted with ether. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with 10% ethyl acetate in hexanes to afford 2-(2-methoxy-6-methylphenyl)-2-propanol (0.60 g, 65 %) as colorless oil: ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.80 (dd, J = 12.0 Hz, 11.7 Hz, 1 H), 6.60 (d, J = 12.0 Hz, 1 H), 6.45 (d, J = 11.7 Hz, 1 H), 4.47 (s, 1

H), 3.52 (s, 3 H), 2.33 (s, 3 H), 1.33 (s, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:5); $R_f = 0.54$.

Step b:

A solution of 2-(2-methoxy-6-methylphenyl)-2-propanol (0.50 g, 2.77 mmol) in ethyl acetate-acetic acid (9:1, 10 .0 mL) at room temperature was stirred under a H_2 atmosphere for 16 h. The mixture was filtered through a Celite plug and the solvent was removed under reduced pressure. The residue was dissolved in hexanes and washed with water. The organic layer was dried $MgSO_4$, filtered and concentrated under reduced pressure to afford 2-*iso*-propyl-3-methylanisole (0.45 g, 100%) as colorless oil, which was used for the next step without further purification: ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.01 (dd, J = 12.0 Hz, 11.7 Hz, 1 H), 6.78 (d, J = 12.0 Hz, 1 H), 6.70 (d, J = 11.7 Hz , 1 H), 3.74 (s, 3 H), 3.28 (m, 1 H), 2.26 (s, 3 H), 1.24 (d, J = 10.8 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); $R_f = 0.80$.

Step c:

To a solution of 2-*iso*-propyl-3-methylanisole (0.44 g, 2.7 mmol) in CH_2Cl_2 at room temperature was added a solution of tetrabutylammonium tribromide (1.42g, 2.94 mmol) in CH_2Cl_2. The reaction mixture was stirred for 2 h and the solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with 5% ethyl acetate in hexanes to afford 4-bromo-2-*iso*-propyl-3-methylanisole as yellowish oil (0.60g, 92%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.37 (d, J = 13.2 Hz, 1 H), 6.78 (d, J = 13.2 Hz , 1 H), 3.74 (s, 3 H), 3.38 (m, 1 H), 2.38 (s, 3 H), 1.25 (d, J = 10.8 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (5:95); $R_f = 0.80$.

The title compound was prepared from 4-bromo-2-*iso*-propyl-3-methylanisole according to the procedure described for the synthesis of compound 7-11: mp: 180-183 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 6.76 (s, 2 H), 6.34 (d, J = 8.4 Hz, 1 H), 6.03 (d, J = 8.4 Hz, 1 H), 4.22 (d, J = 10.5 Hz, 1 H), 3.81 (s, 2 H), 3.50 (m, 1 H), 2.37 (s, 3 H), 2.16 (s, 3 H), 1.39 (d, J = 6.9 Hz, 6 H); LC-MS m/z = 379 $[C_{20}H_{27}O_5P + H]^+$; Anal. Calcd for ($C_{20}H_{27}O_5P$+0.5 H_2O): C, 62.01; H, 7.28. Found: C, 61.98; H, 7.26.

Compound 7-17: [2,5-Dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid

Step a:

To a stirred suspension of 2,5-dimethyl phenol (5.0 g, 40.9 mmol) in H_2O (150 mL), at room temperature was added tetrabutylammonium tribromide (19.9 g, 41.39 mmol) in $CHCl_3$ (150 mL). The reaction mixture was stirred for 2 h at rt, the organic layer was separated and dried over Na_2SO_4, filtered and concentrated. The residue was purified by column chromatography on silica gel eluting with hexane-ethyl acetate (1:5) to afford 2,5-dimethyl-4-bromophenol as a brown solid (6.2 g, 76%); ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.47 (s, 1 H), 7.24 (s, 1 H), 6.74 (s, 1 H), 2.21 (s, 3 H), 2.07 (s, 3 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (9:1); R_f = 0.52.

Step b:

Intermediate 2,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenol was prepared from 2,5-dimethyl-4-bromo-*t*-butyldimethylsilyloxyphenol, and 3-*iso*-propyl-4-methoxymethoxybenzaldehyde according to the procedure described in (G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607) and transformed into the title compound by the procedure used for the synthesis of compound 7-13, step b followed by example 7, step b, (0.14 g, 90%); ^{1}H NMR (300 MHz, CD_3OD): δ 6.88 (d, J = 8.7 Hz, 2 H), 6.79 (s, 1 H), 6.64 - 6.72 (m, 2 H), 4.20 (d, J = 10.2 Hz, 2 H), 3.80 (s, 2 H), 3.10 - 3.15 (m, 1 H), 2.22 (s, 3 H), 2.20 (s, 3 H), 1.17 (d, J = 6.9 Hz, 6 H); LC-MS m/z = 365 $[C_{20}H_{25}O_6P + H]^+$; HPLC conditions: ODSAQ AQ-303-5 column; mobile phase = CH_3OH: 0.05%TFA (7:3) flow rate = 1.0 mL/min; detection = UV @ 254 nm retention time in min: 10.96; Anal Calcd for ($C_{20}H_{25}O_6P$ + 0.3 H_2O): C, 61.84; H, 6.92. Found: C, 61.60; H, 6.72.

Compound 7-18: [2,5-Dimethyl-6-iodo-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid

Step a:

To a stirred solution of 2,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol (intermediate for the synthesis of compound 7-17; 0.35 g, 1.11 mmol) in EtOH (5.0 mL) and CH_3NH_2 40% in water (2.5 mL) was added iodine (0.34 g, 1.33 mmol) and KI (0.27 g 1.66 mmol) in H_2O (3 mL) at 0° C. The reaction mixture was

stirred at 0 °C for 2 h, quenched with brine (50 mL) and extracted with ethyl acetate (100 mLx2). The combined organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:3) to afford 2,5-dimethyl-6-iodo-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol as a colorless oil (0.32 g, 64%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.02 (d, J = 2.4 Hz, 1 H), 6.95 (d, J = 8.7 Hz, 1 H), 6.88 (s, 1 H), 6.75 (dd, J = 2.4, 8.4 Hz, 1 H), 5.20 (s, 2 H), 3.95 (s, 2 H), 3.51 (s, 3 H), 3.35 - 3.30 (m, 1 H), 2.39 (s, 3 H), 2.30 (s, 3 H), 1.22 (d, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethylacetate (9:1); R_f = 0.6.

Step b:

The title compound was prepared from 6-iodo-3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol according to the procedure described for the synthesis of example 7-17, step b as white solid (0.15 g, 75%) mp 190 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 6.99 (s, 1 H), 6.92 (s, 1 H), 6.65 (s, 2 H), 4.16 (d, J = 10.5 Hz, 2 H), 3.94 (s, 2 H), 3.30 - 3.18 (m, 1 H), 2.38 (s, 6 H), 1.18 (d, J = 6.9 Hz, 6 H); LC-MS m/z = 490 $[C_{19}H_{23}I_2O_5P+H]^+$; Anal Calcd for ($C_{20}H_{25}O_6P$ + 1.2 H_2O+1.0 $CHCl_3$): C, 38.05; H, 4.37. Found: C, 38.04; H, 4.33.

<u>**Compound 7-19**: [2,6-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenoxymethyl]phosphonic acid</u>

Intermediate 2,6-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol was prepared from 3,5-dimethyl-4-hydroxy benzaldehyde and bromo-4-methoxymethoxy-3-*iso*-propylbenzene according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound according to the procedure described for the synthesis of compound 7-17, step b; (0.12 g, 85%); ^{1}H NMR (300 MHz, CD_3OD): δ 6.97 (s, 1 H), 6.83 (s, 2 H), 6.77 (d, J = 7.5 Hz, 1 H), 6.65 (d, J = 7.5 Hz, 1 H), 4.0 (d, J = 9.9 Hz, 2 H), 3.75(s, 2 H), 3.20 - 3.29 (m, 1 H), 2.28 (s, 6 H), 1.19 (d, J = 6.6 Hz, 6 H); LC-MS m/z = 363 $[C_{20}H_{25}O_6P - H]^+$; (94%) HPLC conditions: ODSAQ AQ-303-5 column; mobile phase = CH_3OH: 0.05%TFA/H2O (7:3) flow rate = 1.0 mL/min; detection = UV @ 254 nm retention time in min: 10.92; Anal Calcd for ($C_{20}H_{25}O_6P$ + 1.2 H_2O): C, 59.12; H, 7.15. Found: C, 58.96; H, 6.77.

Compound 7-20: [4-(4'-hydroxy-3'-*iso*-propylbenzyl)-3-methyl-phenoxy]methylphosphonic Acid

Intermediate 4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)-3-methyl-phenol was prepared from 4-bromo-3-methyl-phenol (*J. Med. Chem.* **1980**, *12*, 1350) and 4-methoxymethoxy-3-*iso*-propylbenzaldehyde according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure used for the synthesis of compound 7. ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.04 (s, 1 H), 7.02-6.99 (d, J = 8.7 Hz, 1 H), 6.92 (s, 1 H), 6.81-6.76 (m, 2 H), 6.67 (s, 2 H), 4.03 (d, J = 10.5 Hz, 2 H), 3.76 (s, 2 H), 3.16-3.14 (m, 1 H), 2.19 (s, 3 H), 1.14-1.12 (d, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate; R_f = 0.11;

Compound 7-21: [2,5-Dimethyl-4-(4'-methoxy-2'-methyl-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid

Step a:

First step: To a stirring solution of 2,5-dimethyl-4-methoxybenzaldehyde (0.82 g, 5.0 mmol) at - 20 °C in CH_2Cl_2 (10 mL) was added BBr_3 (10 mL, 1M in CH_2Cl_2). The reaction mixture was stirred at room temperature for 16 hrs. It was added ice and diluted with CH_2Cl_2. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate/hexanes (1:1) to afford 2,5-dimethyl-4-hydroxy-benzaldehyde as a yellow solid (0.43 g, 57%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 10.41 (s, 1 H), 9.99 (s, 1 H), 7.56 (s, 1 H), 6.69 (s, 1 H), 2.51 (s, 3 H), 2.14 (s, 3 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 20% ethyl acetate in hexanes; R_f = 0.48.

Step b:

To a stirring solution of 2,5-dimethyl-4-hydroxy-benzaldehyde (0.43 g, 2.86 mmol) in DMF (8 mL) at room temperature was added imidazole (0.43 g, 6.29 mmol) and chloro-triisopropyl-silane (0.74 mL, 3.43 mmol). The mixture was stirred at room temperature for 16 hrs. The solvent was removed under reduced pressure and the residue was partitioned between ethyl acetate and water. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was

purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (15:75) to afford 2,5-dimethyl-4-triisopropylsilanyloxy-benzaldehyde as a colorless oil (0.7 g, 80%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 10.07 (s, 1 H), 7.65 (s, 1 H), 6.69 (s, 1 H), 2.55 (s, 3 H), 2.21 (s, 3 H), 1.35 (m, 3 H), 1.10 (d, J = 6.9 Hz, 18 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 5% ethyl acetate in hexanes; R_f = 0.68.

Intermediate 2,5-dimethyl-4-(4'-methoxy-2'-methyl-3'-*iso*-propylbenzyl) phenol was prepared from 2,5-dimethyl-4-triisopropylsilanyloxy-benzaldehyde and 1-bromo-4-methoxy-2-methyl-3-*iso*-propylbenzene according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607 and transformed into the title compound by the procedure described for the synthesis of compound 7: ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.93 (s, 1 H), 6.75 (d, J = 8.4 Hz, 1 H), 6.65 (d, J = 8.4 Hz, 1 H), 6.64 (s, 1 H), 4.09 (d, J = 9.9 Hz, 2 H), 3.79 (s, 2 H), 3.77 (s, 3 H), 3.34 (m, 1 H), 2.22 (s, 3 H), 2.20 (s, 3 H), 2.10 (s, 3 H), 1.31 (d, J = 7.2 Hz, 6 H); LC-MS m/z = 391 [C21H29O5P - H]$^-$.

Alternative method for the preparation of compound 7:

Step a:

A 3 neck 2 liter flask fitted with mechanical stirring, nitrogen bubbler, sodium hydroxide trap, and a cool water bath was charged with 2-*iso*-propyl phenol (157.8 g,1.1 mol) and dichloromethane (1000 ml). While maintaining the internal temperature at 15 °C to 20 °C, bromine (179.4 g, 1.1 mol) was added dropwise over 45 min. (The rate of addition is controlled so that the bromine color dissipates almost immediately). The reaction was complete by TLC (silica gel plates, 20% EtOAC/hexanes, R_f S.M. = 0.7, R_f product = 0.8). The flask was purged with nitrogen to remove most of the hydrogen bromide. The reaction mixture was then concentrated to an oil (252.0 g, 100%) which is pure enough to use in the next step. NMR: See Berthelot et al. *Can J. Chem.* **1989**. *67*, 2061.

Step b:

A 3 liter 3 neck round bottom flask equipped with mechanical stirring, temperature probe, cooling bath, and addition funnel with nitrogen inlet was charged with 4-bromo-2-*iso*-propylphenol (160 g, 0.75 mol) and methylene chloride (750 ml). While maintaining the temperature between 15 °C and 20 °C, a solution of

diisopropylethylamine (146 g,1.13 mol) and chloromethyl methyl ether (66.4 g, 0.83 mol) in methylene chloride (100 ml) was added over 15 minutes. The solution was heated to reflux for 16 hours. The reaction was complete by TLC (silica gel plates, 10% EtOAC/hexanes, R_f S.M. = 0.5, R_f product = 0.9). After cooling to room temperature, the reaction was quenched by the addition of water (800 ml). After separation of layers, the aqueous phase was extracted with methylene chloride (500 ml). The combined organic layers were dried over $MgSO_4$, and then concentrated to an oil (204 g). The oil was purified by column chromatography (1.8 kg silica gel, 2.5% EtOAc/hexanes) to yield a clear oil (154 g, 79%). NMR See G. Chiellini et al. *Biorg. Med. Chem. Lett.* **2000**, *10*, 2607.

Alternative Step b

A 5 liter 4 neck indented round bottom flask equipped with a mechanical multi-paddle stirrer, and an addition funnel with nitrogen inlet was charged with 4-bromo-2-*iso*-propylphenol (100 g, 0.47 mol) and methylene chloride (2000 ml). Under high agitation, half of the P_2O_5 (75 g, 1.1 mol) was added. The reaction was stirred for one hour during which time dough balls formed. Additional P_2O_5 (75 g, 1.1 mol) was added and stirred for one hour. The reaction was complete by TLC (silica gel plates, 10% EtOAC/hexanes, R_f S.M. = 0.5, R_f product = 0.9). The reaction was carefully quenched by the addition of 10% K_2CO_3 (2000 ml). After separation of layers, the aqueous phase was extracted with methylene chloride (1000 ml). The combined organic layers were dried over $MgSO_4$, and then concentrated to an oil (116 g). The oil was purified by column chromatography (1.5 kg silica gel, 2.5% EtOAc/hexanes) to yield a clear oil (99.9 g, 83%).

Step c:

A 2 liter 3 neck round bottom flask equipped with mechanical stirring, cooling bath, temperature probe, and addition funnel with nitrogen inlet was charged with 4-bromo-3,5-dimethylphenol (90.0 g, 448 mmol), imidazole (90 g, 1.32 mol), and methylene chloride (900 ml). The solution was cooled to 10 °C. Triisopropylsilyl chloride (95.0 g, 493 mmol) was added over 10 minutes. The temperature rose to 20 °C. The solution became turbid, and a white precipitate formed. The reaction mixture was stirred at room temperature for 2.5 hours. The reaction was complete by TLC (silica gel plates, 10 % EtOAc/hexane, R_f S.M. = 0.3, R_f product = 0.9). Water (600 ml) was added

and stirred for 20 minutes. After separation of layers, the organic phase was dried over $MgSO_4$ and concentrated to an oil (178 g) which is acceptable for use in the next step. The oil was purified by column chromatography (1.8 kg silica gel, 5 % EtOAc/hexane) to yield an oil (153 g, 96 %). NMR See G. Chiellini et al. *Biorg. Med. Chem. Lett.* **2000,** *10,* 2607.

Step d:

A 3 liter 3 neck round bottom flask equipped with mechanical stirring, thermometer, cooling bath and 250 ml addition funnel was charged with 4-bromo-3,5-dimethylphenoxytriisopropylsilane (150 g, 420 mmol) and THF (1125 ml). The solution was cooled to –73 °C. While maintaining the temperature at less than or equal to –70 °C, 2.5 M n-butyllithium (252 ml, 630 mmol) was added over 1.5 hours. The solution was stirred at –73 °C for an additional 2.5 hours. While maintaining the temperature at less than or equal to –70 °C, a solution of dimethylformamide (61.3 g, 840 mmol) in THF (60 ml) was added over 35 minutes. After stirring for 30 minutes at –73 °C, TLC indicated that the reaction was complete (silica gel plates, 10 % EtOAc/hexane, R_f S.M. = 0.9, R_f product = 0.7). The reaction was warmed to room temperature, and then quenched by the addition of saturated ammonium chloride in water (1000 ml). After separation of layers, the aqueous phase was extracted with MTBE (250 ml). The combined organic layers were dried over $MgSO_4$, and concentrated to an oil (125 g). The oil was purified by column chromatography (1.5 kg silica gel, 5 % EtOAc/hexanes) to yield an oil (113 g, 87 %). NMR See G. Chiellini et al. *Biorg. Med. Chem. Lett.* **2000,** *10,* 2607.

Step e:

A 5 liter 3 neck round bottom flask equipped with a cooling bath, mechanical stirring, temperature probe, and addition funnel with nitrogen inlet was charged with bromo-4-methoxymethoxy-3-*iso*-propyl (136 g, 525 mmol) and THF (1300 ml). The solution was cooled to –75 °C. While maintaining the temperature at less than or equal to –70 °C, n-butyllithium solution (310 ml, 775 mmol) was added over 45 minutes. The solution was stirred at –75 °C for 1 hour. While maintaining the temperature at less than or equal to –70 °C, a solution of 2,6-dimethyl-4-triisopropylsilyloxybenzaldehyde (134 g, 438 mmol) in THF (200 ml) was added over 2 hours. The solution was stirred at – 75 °C for 1 hour. TLC indicated that the reaction was complete (silica gel plates, 10 % EtOAc/hexane, R_f Bromide = 0.9, R_f Aldehyde = 0.7, R_f product = 0.2). After warming to room temperature, the reaction was quenched with saturated ammonium chloride in

water (200 ml). After separation of layers, the aqueous phase was extracted with ethyl acetate (800 ml). The combined organic layers were washed with brine (700 ml), dried over $MgSO_4$, and concentrated to an oil (262 g). The oil was split into halves, and each half was purified by column chromatography (1.8 kg silica gel, 5 to 10 % EtOAc/hexane) to yield the product as a clear oil containing some EtOAc (148 g of product, 69 %). The fractions containing the product and an impurity were combined to give a clear oil (19.3 g). This was purified by column chromatography (400 g silica gel, 5 to 10 % EtOAc/hexanes) to give additional product as a clear oil (16.9 g, 7 %). NMR See G. Chiellini et al. *Biorg. Med. Chem. Lett.* **2000**, *10*, 2607.

Step f:

A 2 liter round bottom flask equipped with magnetic stirring and a 3 way adapter was charged with (4-methoxymethoxy-3-*iso*-propylphenyl)-(2,6-dimethyl-4-triisopropylsilyloxy)-methanol (72.1 g, 139 mmol), ethyl acetate (665 ml), acetic acid (35 ml), and 10 % Pd on Carbon (5.22 g). The flask was purged 3 times with nitrogen, and then a hydrogen balloon was attached to the adapter. After purging 3 times with hydrogen, the mixture was stirred at room temperature for 3 hours. The reaction was complete by TLC (silica gel plates, 10 % EtOAc/hexane, R_f S.M. = 0.2, R_f product = 0.9). After purging with nitrogen, the mixture was filtered through a small pad of Celite; rinsed with EtOAc (70 ml). The filtrate was washed with water (2 x 100 ml), and then by saturated $NaHCO_3$ in water until the wash was basic (4 x 100 ml). The organic layer was dried over $MgSO_4$ and then concentrated to an oil (62.5 g, 96 %). NMR See G. Chiellini et al. *Biorg. Med. Chem. Lett.* **2000**, *10*, 2607.

Step g:

A 1 liter 1 neck round bottom flask equipped with magnetic stirring was charged with the 2,6-dimethyl-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)-4-triisopropylsilyloxybenzene (62.5 g, 133 mmol) and THF (600 ml). Tetraethylammonium fluoride hydrate (25.9 g, 174 mmol) was slightly ground in a beaker and then charged to the flask. The slurry was stirred at room temperature for 1 hour until TLC indicated that the reaction was complete (silica gel plates, 20 % EtOAc/hexane, R_f S.M. = 0.9, R_f product = 0.4). Water (300 ml) was added and stirred for 15 minutes. The mixture was diluted with MTBE (600 ml), and the layers were separated. The aqueous phase was extracted with MTBE (600 ml). The combined organic layers were washed with water (100 ml) followed by brine (200 ml). After drying over $MgSO_4$, the organic layer was concentrated to an oil (65 g). This was

purified by column chromatography (1300 g silica gel, 10 to 20 % EtOAc/hexanes) to give the product as a clear oil (57.0 g, 95 %). NMR See G. Chiellini et al. *Biorg. Med. Chem. Lett.* **2000**, *10*, 2607.

Step h:

A 5 liter 3 neck round bottom flask equipped with a cooling bath, mechanical stirring, temperature probe, and addition funnel with nitrogen inlet was charged with 60% sodium hydride in mineral oil (10.62 g, 266 mmol). The sodium hydride was washed with hexanes (150 ml). Dimethylformamide (250 ml) was added, and the mixture cooled to 5°C. While maintaining the temperature < 10°C a solution of 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)-phenol (55.53 g, 117 mmol) in DMF (150 ml) was added over 30 minutes. The solution was stirred at room temperature for 1 hour, and then cooled back to 5°C. While maintaining the temperature at less than or equal to 10 °C, a solution of the diethyl *p*-toluenesulfonyloxymethyl-phosphonate (86.93 g, 269 mmol) in DMF (150 ml) was added over 15 minutes. The solution was stirred at room temperature for 16 hours. The reaction was concentrated to a paste. The paste was treated with water (330 ml) and extracted with ethyl acetate (330 ml, 2x 250 ml). The combined organic layers were washed with brine (150 ml), dried over $MgSO_4$, and concentrated to an oil (116 g). The oil was purified by column chromatography (1.5 kg silica gel, 10 to 50 % EtOAc/hexane) to yield the product as a clear oil containing some EtOAc (54.76 g of product, 66 %). The fractions containing the product and diethyl p-toluenesulfonyloxmethyl were combined to give a clear oil (6.03 g). This was purified by column chromatography (120 g silica gel, 30 to 40 % EtOAc/hexanes) to give the product as a clear oil (3.74 g, 4 %). NMR see compound 7, step a.

Step i:

A 500 ml 3 neck round bottom flask equipped with magnetic stirring, temperature probe, addition funnel with a nitrogen inlet, and a cooling bath was charged with the diethyl [3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonate (19.61 g,42.2 mmol) and dichloromethane (200 ml). The solution was cooled to –30 °C. Trimethylsilyl bromide (64.96 g, 424 mmol) was added over 15 min. The bath was removed, and the solution stirred at room temperature for 16 hours. The reaction was concentrated on the rotory evaporator at 50 °C. The oil was then put on the vacuum pump for 30 minutes. The oil was dissolved in acetonitrile/water (110 ml/110 ml) and stirred at 50 °C for 30 min. The solution was

concentrated to an oil. Acetonitrile (110 ml) was added, and the solution was concentrated to an oil. Methanol/toluene (30/190 ml) was added and the solution was concentrated to an oil. Methanol/toluene (30/190 ml) was added and the solution was concentrated to a foam. Toluene (220 ml) was added and the solution was concentrated to a solid. Toluene/hexane (190 ml/30 ml) was added, and the mixture was sonicated for 5 minutes. The solids were scraped down the sides of the flask, and the mixture was stirred at room temperature for 2 hours. The solids were collected by vacuum filtration and washed with hexane/toluene (2 ml/8 ml). The solids were dried overnight in the vacuum oven at 45 to 50 °C to yield MB7344 as an off-white solid (14.36 g). NMR see compound 7, step b.

Preparation of Diethyl p-toluenesulfonyloxymethylphosphonate

A 12 L, 3-neck round bottom flask was equipped with a mechanical stirrer, condenser, thermometer and heating mantle. The flask was flushed with nitrogen and charged with diethyl phosphite (554 g, 3.77 mol), paraformaldehyde (142 g, 4.72 mol), toluene (2 L) and triethylamine (53 mL, 5.76 mol). The mixture was stirred at 85-90 ° for 2 h, then at reflux for 1 h. The resulting yellow solution was cooled to 4 °C (ice bath) and p-toluenesulfonyl choride (718 g, 3.77 mol) was added. The condenser was replaced with an addition funnel and triethylamine (750 mL) was added slowly with stirring, maintaining the temperature <10 °C. After the addition was complete (45 min.), the resulting mixture was stirred at ambient temperature for 14 h. The mixture was filtered and the filtercake was washed with toluene (2 X 250 mL). The combined filtrate and washings were washed with water (2 X 1 L, dried ($MgSO_4$, 200 g), filtered through Celite 521, and concentrated under reduced pressure to provide 1004 g of a cloudy yellow oil (77.6%). ^{1}H NMR ($CDCl_3$): NMR (DMSO): 7.82 (d, J = 8.2 Hz, 2H), 7.48 (d, J = 8.2 Hz, 2H), 4.36 (d, J = 9.6 Hz, 2H), 4.00 (m, 4H), 2.41 (s, 3H), 1.16 (m, 6H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 40% EtOAc/hexanes, Rf = 0.24.

Example 8

Compound 8: [3,5-diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy) phenoxy]methylphosphonic acid

Step a:

To a solution of 4-benzoyloxyphenol (0.2 g, 0.93 mmol) in dichloromethane (9.3 mL) at 0 °C was added bis(pyridine)iodonium tetrafluoroborate (0.76 g, 2.06 mmol). The reaction mixture was stirred at room temperature for 1 h. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:9) to afford 4-benzoyloxy-3,5-diiodophenol as an off-white solid (0.22 g, 50%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.60 (s, 1 H), 8.06 (m, 2 H), 7.72 (s, 2 H), 7.59 (m, 3 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (4:1); R_f = 0.45.

Step b:

To a mixture of bis(4-methoxy-3-*iso*-propylphenyl)iodonium tetrafluoroborate (0.77 g, 1.51 mmol) and copper powder (0.13 g, 2.01 mmol) in CH_2Cl_2 (4.4 mL) at 0 °C was added a solution of TEA (0.15 mL, 1.10 mmol) and 4-benzoyloxy-3,5-diiodophenol (0.47 g, 1.00 mmol) in dichloromethane (4.0 mL). The reaction mixture was stirred at room temperature for 24 h and filtered through a Celite plug. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:9) to afford 3,5-diiodo-4-(4'-methoxy-3'-*iso*-propylphenoxy)phenyl benzoate as an off-white solid (0.61 g, 98%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.10 (m, 2 H), 7.96 (s, 2 H), 7.73 (m, 1 H), 7.60 (m, 2 H), 6.85 (d, J = 9.0 Hz, 1H), 6.73 (d, J = 3.0 Hz, 1H), 6.35 (m, 1 H), 3.74 (s, 3 H), 3.21 (m, 1 H), 1.13 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (1:9); R_f = 0.42.

Step c:

A mixture of 3,5-diiodo-4-(4'-methoxy-3'-*iso*-propylphenoxy)phenyl benzoate (0.10 g, 0.16 mmol) and 1 N NaOH (0.81 mL, 0.81 mmol) in methanol (1.63 mL) was at room temperature for 24 h. The reaction mixture was neutralized with 2 N HCl, diluted with H_2O and extracted with CH_2Cl_2 (10 mLx2). The organic layers were concentrated under reduced pressure and the crude product was purified preparatory TLC with acetone-hexanes (1:4) as mobile phase to afford 3,5-diiodo-4-(4'-methoxy-3'-*iso*-propylphenoxy)phenol as an off-white solid (0.079 g, 95%): ^{1}H NMR (300 MHz,

DMSO-d_6): δ 9.99 (s, 1 H), 7.28 (s, 2 H), 6.81 (d, J = 12.0 Hz, 1 H), 6.67 (d, J = 3.0 Hz, 1 H), 6.30 (m, 1 H), 3.72 (s, 3 H), 3.18 (m, 1 H), 1.11 (d, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (7:3); R_f = 0.42.

Step d:

To a stirred solution of 3,5-diiodo-4-(4'-methoxy-3'-*iso*-propylphenoxy)phenol (0.28 g, 0.55 mmol) in dichloromethane (17.0 mL) at –78 °C was added BBr_3 (13.1 mL, 13.1 mmol, 1.0 M solution in CH_2Cl_2). The reaction mixture was stirred at –78 °C for 10 min, allowed to warm to room temperature and stirred for 16 h. The reaction mixture was poured into ice and extracted with CH_2Cl_2 (20 mLx2). The organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (3:7) to afford 3,5-diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenol as an off-white solid (0.18 g, 66%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.95 (s, 1 H), 8.91 (s, 1 H), 7.27 (s, 2 H), 6.62 (d, J = 9.0 Hz, 1 H), 6.56 (d, J = 3.0 Hz, 1 H), 6.18 (m, 1 H), 3.72 (s, 3 H), 3.14 (m, 1 H), 1.10 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (7:3); R_f = 0.28.

Step e:

To a mixture of 3,5-diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenol (0.067 g, 0.14 mmol) and Cs_2CO_3 (0.220 g, 0.675 mmol) in DMF (1.35mL) at 0 °C was added trifluoromethanesulfonic acid diethoxyphosphorylmethyl ester (0.040 g, 0.14 mmol). The reaction mixture was stirred at room temperature for 5 h, quenched with 1 N HCl and extracted with EtOAc (10 mLx2). The organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The residue was purified by preparatory TLC with acetone-hexane (2:3) as mobile phase to afford diethyl [3,5-diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenoxy]methylphosphonate as an off-white solid (0.048 g, 55%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.95 (s, 1 H), 7.57 (s, 2 H), 6.63 (d, J = 9.0 Hz, 1 H), 6.56 (d, J = 3.0 Hz, 1 H), 6.19 (m, 1 H), 4.51 (d, J = 9.0 Hz, 2 H), 4.08 (m, 4 H), 3.14 (m, 1 H), 1.25 (m, 6 H), 1.10 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (3:2); R_f = 0.29.

Step f:

To a solution of diethyl [3,5-diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy) phenoxy]methylphosphonate (0.14 g, 0.22 mmol) in CH_2Cl_2 (2.5 mL) at 0 °C was added

bromotrimethylsilane (0.28 mL, 2.20 mmol). The reaction mixture was stirred at room temperature 16 h and the solvent was removed under reduced pressure. The residue was treated with acetonitrile-water (1:1, 5.0 mL) and solvent was removed under reduced pressure. The crude product was treated methanol (10 mL) and the solvent was removed under reduced pressure to afford [3,5-diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy) phenoxy]methylphosphonic acid as an off-white solid (0.080 g, 63%): mp 180 °C, dec; LC-MS m/z = 589 $[C_{16}H_{17}I_2O_6P - H]^-$; HPLC conditions: Column = 3 Chromolith SpeedRODs RP-18e, 100×4.6 mm; Mobile phase = Solvent A (Acetonitrile) = HPLC grade acetonitrile; Solvent B (buffer) = 20 mM ammonium phosphate buffer (pH 6.1, 0.018 M $NH_4H_2PO_4$/0.002 M $(NH_4)_2HPO_4$) with 5% acetonitrile. Flow rate = 4 mL/min; UV@ 255 nm. Retention time in minutes. (rt = 6.46, 97% purity).

Using the appropriate starting material, compounds 8-1 and 8-2 were prepared in an analogous manner to that described for the synthesis of compound 8.

<u>**Compound 8-1:** [3,5-dibromo-4-(3'-*iso*-propyl-4'-hydroxyphenoxy)phenoxy]methylphosphonic acid</u>

Prepared from 4-benzoyloxy-3,5-dibromophenol according to the procedure described in compound 8.

mp: 77-80 °C; LC-MS m/z = 495,497 $[C_{16}H_{17}Br_2O_6P - H]^-$; ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.99 (s, 1 H), 7.42 (s, 2 H), 6.63 (m, 2 H), 6.22 (m, 1 H), 4.21 (d, J = 9.0 Hz, 2 H), 3.11 (m, 1 H), 1.10 (d, J = 6.0 Hz, 6 H); Anal. Calcd for ($C_{16}H_{17}Br_2O_6P$ + 0.2 C_6H_{14}): C, 40.06; H, 3.78. Found: C, 40.25, H, 3.89.

<u>**Compound 8-2:** [3,5-dichloro-4-(3'-*iso*-propyl-4'-hydroxyphenoxy)phenoxy]methylphosphonic acid</u>

Prepared from 2,6-dichloro-4-(2-methoxyethoxy)phenol (*Synth. Commu.* **1997**, *27*, 107) according to the procedure described in compound 8.

mp: 73-76 °C; LC-MS m/z = 407 $[C_{16}H_{17}Cl_2O_6P - H]^-$; ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.10 (s, 1 H), 7.34 (s, 2 H), 6.72 (m, 2 H), 6.32 (m, 1 H), 4.28 (d, J = 9.0 Hz, 2 H), 3.22 (m, 1 H), 1.17 (d, J = 6.0 Hz, 6 H); Anal. Calcd for ($C_{16}H_{17}Cl_2O_6P$ + 0.2 $C_4H_8O_2$ + 0.4 H_2O): C, 46.71; H, 4.53. Found: C, 46.95, H, 4.50.

Example 9

Compound 9: 3,5-dichloro-4-[4'-hydroxy-3'-(*N*-piperidinylsulfonamido) phenoxy]benzylphosphonic acid

Step a:

To a stirred solution of bis(4-methoxyphenyl)iodonium tetrafluoroborate (5.2 g, 13.5 mmol, N. Yokoyama *et al. J. Med. Chem.* **1995**, *38*, 695) and copper powder (1.14 g, 18.1 mmol) in CH_2Cl_2 (30 mL) at 0 °C was added a solution of methyl 3,5-dichloro-4-hydroxybenzoate (39, 2.0 g, 9.0 mmol) and Et_3N (1.1 g, 1.5 mL, 12.0 mmol) in CH_2Cl_2 (10 mL). The reaction mixture was stirred at room temperature for 24 h and filtered through a Celite plug. The filtrate was washed with 2 N HCl (20 mL) and extracted with ethyl acetate (2x100 mL). The combined organic layers were washed with brine and water, dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1: 9) to afford methyl 3,5-dichloro-4-(4'-methoxyphenoxy)benzoate as a white solid (1.59 g, 55%): mp 82-85 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.04 (s, 2 H), 6.85 (dd, J = 2.7, 4.8 Hz, 1 H), 6.80 (dd, J = 1.8, 4.5 Hz, 1 H), 6.78 (t, J = 3.3 Hz, 1 H), 6.74 (d, J = 2.4 Hz, 1 H), 3.94 (s, 3 H), 3.76 (s, 3 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:4); R_f = 0.7.

Step b:

To a stirred solution of methyl 3,5-dichloro-4-(4'-methoxyphenoxy)benzoate (1.5 g, 4.5 mmol) in CH_2Cl_2 (50 mL) at -78 °C was added BBr_3 (11. 4 mL, 11.4 mmol, 1 M solution in CH_2Cl_2). The reaction mixture was stirred at room temperature for 14 h, poured into ice water (100 mL) and stirred for 1 h. The reaction mixture was extracted with ethyl acetate (2x100 mL). The combined organic layers were washed with water and brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was recrystallized from CH_2Cl_2, filtered and dried under reduced pressure to afford 3,5-dichloro-4-(4'-hydroxyphenoxy)benzoic acid as a brown solid (1.02 g, 75%): mp 163-165 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.02 (bs, 1 H), 8.0 (s, 2 H), 6.67 (m, 4 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:3); R_f = 0.3.

Step c:

To a stirred cold solution of CH_3OH (35 mL) and acetyl chloride (7 mL, 86.0 mmol) at 0 °C was added dropwise a solution of 3,5-dichloro-(4'-hydroxy phenoxy)benzoic acid (1.3 g, 4.3 mmol) in CH_3OH (5 mL). The reaction mixture was heated under reflux for 5 h and cooled to room temperature. The solvent was removed under reduced pressure and the residue was dissolved in ethyl acetate (100 mL). The resulting solution was washed with water and brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was triturated with hexane-ether (8:2), filtered and dried under reduced pressure to afford methyl ,5-dichloro-4-(4'-hydroxyphenoxy) benzoate as a brown solid (1.22 g, 90%): mp 152 -155 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.22 (s, 1 H), 8.08 (s, 2 H), 6.77 (t, J = 3.0 Hz, 1 H), 6.74 (t, J = 2.7 Hz, 1 H), 6.72 (t, J = 2.7Hz, 1 H), 6.68 (d, J = 2.7 Hz, 1 H), 3.87 (s, 3H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:3); R_f = 0.5.

Step d:

To a stirred solution of methyl 3,5-dichloro-4-(4'-hydroxyphenoxy)benzoate (1.2 g, 3.8 mmol) in $CHCl_3$ (10 mL) at 0 °C was added chlorosulfonic acid (3.9 mL, 38.3 mmol). The reaction mixture was stirred at 0 °C for 1 h and allowed to warm to room temperature. The reaction mixture was stirred for 2 h, poured into ice water and extracted with ethyl acetate (3x100 mL). The combined organic layers were washed with water, dried over $MgSO_4$ and concentrated under reduced pressure to afford the crude product, which was used in the next step without purification. The crude product (1.1g, 2.6 mmol) was dissolved in THF (10 mL) and to it was added a solution of piperidine (0.68 g, 1 mL) in THF (5 mL). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was dissolved in ethyl acetate (50 mL) and washed with water and brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (3:7) to afford desired methyl 3,5-dichloro-4-[4'-hydroxy-3'-(*N*-piperidinylsulfonamido) phenoxy]benzoate as a white solid (0.78 g, 60%): mp 122-125 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.58 (s, 1 H), 7.04 - 7.10 (m, 2 H), 6.85 (d, J = 2.7 Hz, 2 H), 3.96 (s, 3 H), 3.02 (t, J = 5.1 Hz, 4 H),

1.63 - 1.59 (m, 4 H), 1.50 - 1.40 (m, 2 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (3:7); R_f = 0.35.

Step e:

To a stirred solution of methyl 3,5 dichloro-4-[4'-hydroxy-3'-(*N*-piperidinylsulfonamido)phenoxy]benzoate (0.95 g, 2.0 mmol) in CH_2Cl_2 (15 mL) at –78 °C was added DIBAL-H (6.1 mL, 6.1 mmol, 1 M solution in CH_2Cl_2). The reaction mixture was stirred at room temperature for 5 h, cooled to 0 °C, quenched with saturated aqueous NaF solution (20 mL) and stirred at room temperature for 1 h. The reaction mixture was filtered and the filtrate was extracted with ethyl acetate (2x100 mL). The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:4) to afford 3,5-dichloro-4-[4'-hydroxy-3'-(*N*-piperidinylsulfonamido)phenoxy]benzyl alcohol as a white solid (0.66 g, 75%): mp 142 -145 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.54 (s, 1 H), 7.40 (s, 2 H), 7.09 (dd, J = 3.0, 9.3 Hz, 1 H), 6.98 (dd, J = 3.0, 9.3Hz, 1 H), 6.84 (d, J = 2.4 Hz, 1 H), 4.70 (d, J = 3.9 Hz, 2 H), 3.02 (t, J = 2.4 Hz, 4 H), 1.70 - 1.50 (m, 4 H), 1.47 - 1.50 (m, 2 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:3); R_f = 0.4.

Step f:

To a stirred solution of 3,5-dichloro-4-[4'-hydroxy-3'-(*N*-piperidinylsulfonamido) phenoxy]benzyl alcohol (0.40 g, 0.92 mmol) in ethyl ether-DME (9:1, 10 mL) at 0 °C was added phosphorous tribromide (1.2 g, 0.5 mL, 4.64 mmol). The reaction mixture was stirred at 0 °C for 5 h, quenched with ice (10 g) and stirred at 0 °C for 30 min. The reaction mixture was extracted with ether (100 mL) and washed with brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:4) to afford 3,5-dichloro-4-[4'-hydroxy-3'-(*N*-piperidinylsulfonamido) phenoxy]benzyl bromide as a colorless oil (0.34 g, 75%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.57 (s, 1 H), 7.42 (s, 2 H), 7.0 (dd, J=3.0, 9.3 Hz, 1 H), 6.97 (d, J = 9.3 Hz, 1 H), 6.86 (d, J = 2.7 Hz, 1 H), 4.41 (s, 2 H), 3.02 (t, J = 5.1 Hz, 4 H), 1.65 - 1.55 (m, 4 H), 1.50 - 1.45 (m, 2 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (3:7); R_f = 0. 75.

Step g:

To a stirred a solution of 3,5-dichloro-4-[4'-hydroxy-3'-(*N*-piperidinylsulfonamido)phenoxy]benzyl bromide (0.12 g, 0.25 mmol) in toluene (5 mL) at room temperature was added triethylphosphite (0.42 g, 2.5 mmol). The reaction mixture was heated at 130 °C for 8 h and cooled to room temperature. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl 3,5-dichloro-4-[4'-hydroxy-3'-(*N*-piperidinylsulfonamido)phenoxy]benzylphosphonate as a white solid (0.12 g, 90%): mp 132 -135 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.55 (s, 1 H), 7.33 (d, J = 2.7 Hz, 2 H), 7.05 (dd, J = 3.0, 9.3 Hz,1 H), 6.97 (d, J = 9.3 Hz, 1 H), 6.83 (d, J = 3.3 Hz, 1 H), 4.09 (q, J = 6.9 Hz, 4 H), 3.07 (d, J = 21.6, 2 H), 3.02 (t, J = 6.0 Hz, 4 H), 1.67- 1.57 (m, 4 H), 1.50 - 1.42 (m, 2 H), 1.30 (t, J = 9.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:1); R_f = 0.4.

Step h:

To a stirred solution of diethyl 3,5-dichloro-4-[4'-hydroxy-3'-(*N*-piperidinylsulfonamido)phenoxy]benzylphosphonate (0.1 g, 0.18 mmol) in CH_2Cl_2 (5 mL) at 0 °C was added TMSBr (0.27 g, 0.3 mL, 1.8 mmol). The reaction mixture was stirred at 0 °C for 30 min, allowed to warm to room temperature and stirred for 16 h. The solvent was removed under reduced pressure and the residue was dissolved in CH_3OH (3 mL). The solvent was removed under reduced pressure. The residue was triturated with water (3 mL). The mixture was filtered and dried under reduced pressure to afford

3,5-dichloro-4-[4'-hydroxy-3'-(*N*-piperidinylsulfonamido)phenoxy)]benzylphosphonic acid as a white solid (0.07 g, 78%): mp 68 -72 °C; LC-MS m/z = 496 $[C_{18}H_{20}Cl_2NO_7PS+H]^+$; Anal Calcd for ($C_{20}H_{16}Cl_2FO_5P$+$0.5CH_2Cl_2$): C, 41.28; H, 3.93; N, 2.60; S, 5.96. Found: C, 41.27; H, 3.86; N, 2.84; S, 5.84.

Example 10

Compound 10: 3,5-dichloro-4-[4'-hydroxy-3'-(*N*-*exo*-2-norbornylsulfonamido) phenoxy]benzylphosphonic acid

Step a:

Methyl 3,5-dichloro-4-[4'-hydroxy-3'-(*N*-*exo*-2-norbornylsulfonamido) phenoxy]benzoate was synthesized as a white solid (0.89 g, 55%) from

methyl-3,5-dichloro-4-(4'-hydroxy)phenoxybenzoate (1.3 g, 3.1 mmol) by following the procedure described in example 9, step d: mp 142 - 145 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.43 (s, 1 H), 8.05 (s, 2 H), 7.06 (dd, *J* = 3.0, 8.7 Hz, 1 H), 6.98 (d, *J* = 9.3 Hz, 1 H), 6.92 (d, *J* = 3.0 Hz, 1 H), 4.53 (d, *J* = 7.5 Hz, 1 H), 3.95 (s, 3 H), 3.12 (m, 1 H), 2. 20 (bs, 1 H), 2.04 (bs, 1 H), 1.66 - 1.58 (m, 2 H), 1.46 - 1.40 (m, 2 H), 1.28 - 1.24 (m, 2 H), 1.20 - 1.16 (m, 1 H), 1.02 (dd, *J* = 1.8, 7.8 Hz, 2 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:3); R_f = 0.3.

Step b:

3,5-Dichloro-4-[4'-hydroxy-3'-(*N-exo*-2-norbornylsulfonamido)phenoxy]benzyl alcohol was prepared as a white solid (0.46 g, 85%) from methyl 3,5-dichloro-4-[4'-hydroxy-3'-(*N-exo*-2-norbornylsulfonamido)phenoxy]benzoate (0.5 g, 0.97 mmol) by following the procedure described in example 9, step e: mp 130 - 132 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.51 (s, 2 H), 7.03 (dd, *J* = 3.3, 9.0 Hz, 1 H), 6.89 (d, *J* = 8.7 Hz, 1 H), 6.81 (d, *J* = 3.0 Hz, 1 H), 4.51 (s, 2 H), 2.90 (dd, *J* = 4.2, 8.1 Hz, 1 H), 2.06 (bs, 1 H), 1.86 (bs, 1 H), 1.37 (dd, *J* = 10.2, 24.3 Hz, 2 H), 1.30 - 1.22 (m, 2 H), 0.98 - 0.90 (m, 2 H), 0.85 - 0.79 (m, 2 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:3); R_f = 0.3.

Step c:

3,5-Dichloro-4-[4'-hydroxy-3'-(*N-exo*-2-norbornylsulfonamido)phenoxy]benzyl bromide was prepared as a colorless oil (0.08 g, 75%) from 3,5-dichloro-4-[4'-hydroxy-3'-(*N-exo*-2-norbornylsulfonamido)phenoxy]benzyl alcohol (0.1 g, 0.20 mmol) by following the procedure described in example 9, step f: ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.33 (s, 1 H), 7.34 (s, 2 H), 7.0 (dd, *J* = 3.0, 8.7 Hz, 1 H), 6.90 (d, *J* = 9.0 Hz, 1 H), 6.85 (d, *J* = 3.0 Hz, 1 H), 4.33 (s, 2 H), 3.05 (m, 1 H), 2.14 (bs, 1 H), 1.97 (bs, 1 H), 1.59 - 1.49 (m, 2 H), 1.38 - 1.32 (m, 2 H), 1.21 - 1.16 (m, 2 H), 1.12 - 1.06 (m, 1 H), 0.95 (dd, *J* = 1.8, 8.1 Hz, 1 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:3); R_f = 0.75.

Step d:

Diethyl 3,5-dichloro-4-[4'-hydroxy-3'-(*N-exo*-2-norbornylsulfonamido) phenoxy]benzylphosphonate was prepared as a colorless oil (0.2 g, 83%) from 3,5-dichloro-4-[4'-hydroxy-3'-(*N-exo*-2-norbornylsulfonamido)phenoxy]benzyl bromide (0.22 g, 0.40 mmol) by following the procedure described in example 9, step g: ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.47 (s, 1 H), 7.33 (d, *J* = 2.7 Hz, 2 H), 7.09 (dd, *J* = 2.7, 8.7 Hz, 1

H), 6.97 (dd, J = 2.7, 9.0 Hz, 1 H), 6.88 (d, J = 3.0 Hz,1 H), 4.75 (d, J = 7.2 Hz, 1 H), 4.09 (q, J = 6.9 Hz, 2 H), 3.49 (s, 1 H), 3.14 (d, J = 21.6 Hz, 2 H), 3.11 - 3.05 (m, 1 H), 2.2 (bs, 1 H), 2.05 (d, J = 3.3 Hz, 1 H), 1.44 - 1.22 (m, 6 H), 1.20 - 1.15 (m, 1 H), 1.14 - 1.02 (m, 1 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:3); R_f = 0.3.

Step e:

3,5-Dichloro-4-[3'-(*N*-*exo*-2-norbornylsulfonamido)-4'-hydroxyphenoxy]benzylphosphonic acid was prepared as a white solid (50 mg, 75%) from diethyl 3,5-dichloro-4-[3'-(*N*-*exo*-2-norbornylsulfonamido)-4'-hydroxyphenoxy]benzylphosphonate (0.075 g, 0.40 mmol) by following the procedure described in example 9, step h: mp 210 - 212 °C; LC-MS m/z = 522 $[C_{20}H_{22}Cl_2NO_7PS]^+$; Anal Calcd for ($C_{20}H_{22}Cl_2NO_7PS$ + 0.7 CH_2Cl_2): C, 42.78; H, 4.06; N, 2.41. Found: C, 42.77; H, 4.17; N, 2.62.

Example 11

Compound 11: 3,5-dichloro-4-[3'-(4-fluorobenzyl)-4'-hydroxyphenoxy] benzylphosphonic acid

Step a:

To a stirred solution of methyl 3,5-dichloro-(4'-hydroxyphenoxy)benzoate (0.5 g, 1.52 mmol) and *p*-fluorobenzoyl chloride (0.69 g, 0.45 mL 3.8 mmol) in CH_2Cl_2 (50 mL) at room temperature was added $TiCl_4$ (7.6 mL, 7.6 mmol, 1 M solution in CH_2Cl_2). The reaction mixture was stirred at room temperature for 8 days, quenched with saturated aqueous NH_4Cl (25 mL) and stirred for 2 h. The reaction mixture was extracted with CH_2Cl_2 (2x100 mL). The combined organic layers were washed with brine, dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was triturated with hexanes-ethyl ether (8:2), filtered and dried under reduced pressure to afford methyl 3,5-dichloro-4-[3'-(4-fluorobenzoyl)-4'-methoxyphenoxy]benzoate as a yellow solid. (0.39 g, 62%): mp 112 - 115 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.04 (s, 2 H), 7.81 (dd, J = 5.7, 9.0 Hz, 2 H), 7.09 (t, J = 8.4 Hz, 2 H), 6.93 (d, J = 2.7 Hz, 1 H), 6.92 (s, 1 H), 6.81 (d, J = 3.0 Hz, 1 H), 3.94 (s, 3 H), 3.69 (s, 3 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:4); R_f = 0.75.

Step b:

To a stirred solution of methyl 3,5-dichloro-4-[3'-(4-fluorobenzoyl)-4'-methoxyphenoxy]benzoate (350 mg, 0.78 mmol) and TFA (2 mL) in CH_2Cl_2 (50 mL) at room temperature was added triethylsilane (0.5 mL, 3.1 mmol). The reaction mixture

was stirred at room temperature for 16 h, quenched with water (25 mL) and extracted with ether (100 mL). The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was triturated with hexanes, filtered and dried under reduced pressure to afford methyl 3,5-dichloro-4-[3'-(4-fluorobenzyl)-4'-methoxyphenoxy]benzoate as a brown solid (0.31 g, 92%): mp 108 -110 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.98 (s, 2 H), 7.06 (dd, J = 6.0, 9.0 Hz, 2 H), 6.88 (t, J = 8.7 Hz, 2 H), 6.70 (d, J = 9.0 Hz, 1 H), 6.58 (d, J = 3.0 Hz,1 H), 6.48 (dd, J = 3.3, 9.0 Hz, 1 H), 3.89 (s, 3 H), 3.83 (s, 2 H), 3.71 (s, 3 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:8); R_f = 0.8.

Step c:

To a stirred suspension of $LiAlH_4$ (0.26 g, 6.95 mmol) in THF (40 mL) at 0 °C was slowly added a solution of methyl 3,5-dichloro-4-[3'-(4-fluorobenzyl)-4'-methoxyphenoxy]benzoate (1.2 g, 2.76 mmol) in THF (10 mL). The reaction mixture was stirred at room temperature for 20 h and cooled to 0 °C. The reaction mixture was quenched with 15% aqueous NaOH (1.5 mL), diluted with H_2O (3.0 mL) and stirred for 1 h. The reaction mixture was filtered through a Celite plug and the filtrate was extracted with ethyl acetate (100 mL). The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford 3,5-dichloro-4-[3'-(4-fluorobenzyl)-4'-methoxyphenoxy]benzyl alcohol as an oil (0.78 g, 70%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.47 (s, 2 H), 7.16 (dd, J = 6.0, 8.7 Hz, 2 H), 7.04 (t, J = 8.7 Hz, 2 H), 6.84 (d, J = 9.0 Hz, 1 H), 6.67 (d, J = 3.0 Hz, 1 H), 6.45 (dd, J = 5.4, 9.3 Hz, 1 H), 5.45 (t, J = 5.7 Hz, 1 H), 4.48 (d, J = 5.7 Hz, 2 H), 3.82 (s, 2 H), 3.69 (s, 3 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:3); R_f= 0.45.

Step d:

To a stirred solution of 3,5-dichloro-4-[3'-(4-fluorobenzyl)-4'-methoxyphenoxy] benzyl alcohol (0.53 g, 1.29 mmol) in CH_2Cl_2 (20 mL) at -78 °C was added BBr_3 (0.82 g, 3.2 mmol). The reaction mixture was stirred at room temperature for 16 h, poured into ice water (100 mL) and extracted with CH_2Cl_2 (200 mL). The organic layer was washed with brine, dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluted with ethyl acetate-hexanes (1:4) to afford 3,5-dichloro-4-[3'-(4-fluorobenzyl)-4'-hydroxyphenoxy]

benzyl bromide as a colorless oil (0.4 g, 67%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.39 (s, 2 H), 7.14 (dd, J = 5.4, 8.7 Hz, 2 H), 6.95 (t, J = 8.7 Hz, 2 H), 6.66 (d, J = 9.0 Hz, 1 H), 6.62 (d, J = 2.7 Hz, 1 H), 6.53 (dd, J = 3.0, 8.7 Hz, 1 H), 4.04 (s, 2 H), 3.90 (s, 2 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:4); R_f = 0.8.

Step e:

To a stirred solution of 3,5-dichloro-4-[3'-(4-fluorobenzyl)-4'-hydroxyphenoxy] benzyl bromide (0.25 g, 0.55 mmol) in toluene (5 mL) at room temperature was added triethylphosphite (0.91 g, 5.5 mmol). The reaction mixture was heated at 120 °C for 8 h and cooled to room temperature. The solvent was removed under reduced pressure and the crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl 3,5-dichloro-4-[3'-(4-fluorobenzyl)-4'-hydroxyphenoxy]benzyl phosphonate as a colorless oil (0.2 g, 68%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.29 (d, J = 2.7 Hz, 2 H), 7.15 (dd, J = 5.4, 9.0 Hz, 2 H), 6.95 (t, J = 8.7 Hz, 2 H), 6.66 (d, J = 4.8 Hz, 1 H), 6.65 (s, 1 H), 6.46 (dd, J = 3. 0, 8.7 Hz, 1 H), 4.07 (q, J = 7.2 Hz, 4 H), 3.89 (s, 2 H), 3.04 (d, J = 21.3 Hz, 2 H), 1.27 (t, J = 7.2 Hz,3 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:1); R_f = 0.3.

Step f:

To a stirred solution of diethyl 3,5-dichloro-4-[3'-(4-fluorobenzyl)-4'-hydroxyphenoxy]benzyl phosphonate (0.09 g, 0.18 mmol) in CH_2Cl_2 (5 mL) at 0 °C was added TMSBr (0.28 g, 0.3 mL). The reaction mixture was stirred at 0 °C for 30 min, allowed to warm to room temperature. The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was dissolved in CH_3OH (5 mL) and the solvent was removed under reduced pressure. The residue was triturated with water (3 mL), filtered and dried under reduced pressure to afford 3,5-dichloro-4-[3'-(4-fluorobenzyl)-4'-hydroxyphenoxy]benzylphosphonic acid as a white solid (0.075 g, 94%): mp 207-210 °C; LC-MS m/z = 457 [$C_{20}H_{16}Cl_2FO_5P$+H]$^+$; Anal Calcd for ($C_{20}H_{16}Cl_2FO_5P$ + 0.8 CH_2Cl_2): C, 47.78; H, 3.39. Found: C, 47.78; H, 3.39.

Example 12

Compound 12-1: di(pivaloyloxymethyl) [3,5-Dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonate

To a mixture of [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)- phenoxy] methylphosphonic acid (0.2 g, 0.5 mmol) and *N, N*-diisopropylethylamine (0.57 mL, 3.0 mmol) in CH_3CN (5.0 mL) at 0 °C was added pivaloyloxymethyl iodide (0.6 mL, 3.0mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:3) to afford the title compound as a white solid (0.22 g, 76%): ^{1}H NMR (300 MHz, CD_3OD): δ 6.79 (d, J= 3.0 Hz, 1 H), 6.68 (s, 2 H), 6.45-6.60 (m, 2 H), 5.75 (m, 4 H), 4.44 (d, J= 9.9 Hz, 2 H), 3.88 (s, 2 H), 3.20 (m, 1 H), 2.20 (s, 6 H), 1.20 (s, 18 H), 1.12 (d, J= 7.2 Hz, 6 H); LC-MS m/z = 593 $[C_{31}H_{45}O_9P + H]^+$; Anal. Calcd for ($C_{31}H_{45}O_9P$+0.3 H_2O): C, 62.26; H, 7.69. Found: C, 62.15; H, 7.77.

Using the appropriate starting material, compounds 12-2 and 12-9 were prepared in an analogous manner to that described for the synthesis of compound 12-1.

Compound 12-2: di(ethoxycarbonyloxymethyl) [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy] methylphosphonate:

^{1}H NMR (300 MHz, DMSO-d_6): δ 9.01 (s, 1 H), 6.86 (s, 1 H), 6.73 (s, 2 H), 6.63-6.61 (m, 1 H), 6.47-6.45 (m, 1 H), 5.72 (s, 2 H), 5.68 (s, 2 H), 4.51-4.48 (d, J= 7.5 Hz, 2 H), 4.17-4.12 (m, 4 H), 3.82 (s, 2 H), 3.13 (m, 1 H), 2.18-2.16 (m, 6 H), 1.23-1.18 (m, 6 H), 1.12-1.10 (d, J= 6.0 Hz, 6 H); LC-MS m/z = 569 $[C_{27}H_{37}O_{11}P + H]^+$; Anal. Calcd for ($C_{27}H_{37}O_{11}P$): C, 57.04; H, 6.56. Found: C, 56.60, H, 6.14.

Compound 12-3:di(isopropoxycarbonyloxymethyl) [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonate:

^{1}H NMR (300 MHz, DMSO-d_6): δ8.97 (s, 1 H), 6.81 (s, 1 H), 6.69 (s, 2 H), 6.59-6.56 (m, 1 H), 6.43-6.40 (m, 1 H), 5.68 (s, 2 H), 5.63 (s, 2 H), 4.81-4.73 (m, 2 H), 4.46-4.43 (d, J= 7.5 Hz, 2 H), 3.78 (s, 2 H), 3.12-3.07 (m, 1 H), 2.14 (s, 6 H), 1.21-1.16 (m, 12 H), 1.08-1.06 (d, J= 6.0 Hz, 6 H); LC-MS m/z = 597 $[C_{29}H_{41}O_{11}P + H]^+$; Anal. Calcd for ($C_{29}H_{41}O_{11}P$): C, 58.38; H, 6.93. Found: C, 58.10, H, 7.54.

<u>**Compound 12-4:** Di-(pivaloyloxymethyl) [3,5-dimethyl-4-(4'-hydroxy-3'-*sec*-butylbenzyl)phenoxy]methylphosphonate:</u>

^{1}H NMR (300 MHz, DMSO-d_6): δ 8.95 (s, 1H), 6.76 (s, 1H), 6.72 (s, 2H), 6.64-6.61 (d, 1H), 6.65-6.47 (d, 1H), 5.73 (s, 2H), 5.68 (s, 2H), 4.48-4.45 (d, 2H), 3.81 (s, 2H), 2.93-2.90 (q, 1H), 2.17 (s, 6H), 1.52-1.44 (m, 2H), 1.17-1.11 (m, 18H), 1.08-1.06 (d, 3H), 0.78-0.73 (t, 3H); LC-MS *m/z* = 607.2 $[C_{32}H_{47}O_9P + H]^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (3:7); R_f = 0.56; Anal. Calcd for ($C_{32}H_{47}O_9P + 0.25\ C_3H_6O$): C, 63.32; H, 7.87. Found: C, 63.72; H, 8.19.

<u>**Compound 12-5:** Di-(pivaloyloxymethyl) [3,5-dibromo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzyl] phosphonate:</u>

mp: 90-91 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.07 (s, 1H), 7.66 (s, 1H), 6.68-6.66 (m, 2H), 6.26-6.22 (d, 1H), 5.67-5.58 (q, 4H), 3.56-3.48 (d, 2H), 3.19-3.14 (m, 1H), 1.19-1.11 (m, 24H); LC-MS *m/z* = 709.4 $[C_{28}H_{37}Br_2O_9P + H]^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (3:7); R_f = 0.50; Anal. Calcd for ($C_{28}H_{37}Br_2O_9P$): C, 47.48; H, 5.26. Found: C, 47.09; H, 4.87.

<u>**Compound 12-6:** Di-(pivaloyloxymethyl) [3,5-dimethyl-4-(3'-(4-fluorobenzyl)-4'-hydroxy-benzyl)phenoxy]methylphosphonate:</u>

^{1}H NMR (300 MHz, DMSO-d_6): δ 9.17(1H, s), 7.18–7.02(m, 3H), 6.71-6.64 (m, 4H), 6.54 (m, 1H), 4.45 (d, 2H, J = 10Hz), 3.76 (s, 4H), 2.12 (s, 6H), 1.13 (s, 18H); LC-MS *m/z* = 633 $[C_{33}H_{44}O_9P + H]^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate 50% in hexane; R_f = 0.48; Anal. Calcd for ($C_{33}H_{44}FO_9P$ +0.5 H_2O): C, 62.99; H, 6.90. Found: C, 62.99; H, 6.90.

<u>**Compound 12-7:** Di(pivaloyloxymethyl) [3,5-diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenoxy]methylphosphonate</u>

mp: 144-147 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.99 (s, 1 H), 7.59 (s, 2 H), 6.68 (m, 1 H), 6.56 (m, 1 H), 6.25 (m, 1 H), 5.73 (d, J = 12.0 Hz, 2 H), 4.64 (d, J = 10.5 Hz, 2 H), 3.16 (m, 1 H), 1.17 (m, 18 H), 1.12 (d, J = 6.0 Hz, 6 H); LC-MS *m/z* = 819 $[C_{28}H_{37}O_{10}I_2P + H]^+$; HPLC conditions: Column = Agilent Zorbax SB-Aq RP-18 filter,

150×3.0; Mobile phase = Solvent A (Acetonitrile) = HPLC grade acetonitrile; Solvent B (buffer) = 20 mM ammonium phosphate buffer (pH 6.1, 0.018 M $NH_4H_2PO_4$/0.002 M $(NH_4)_2HPO_4$). Flow rate = 1.0 mL/min; UV@ 255 nm. Retention time in minutes. (rt = 14.66/25.00, 93% purity); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:1); R_f = 0.39.

Compound 12-8: Di(pivaloyloxymethyl) [3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonate

^{1}H NMR (200 MHz, DMSO-d_6): δ 9.09 (s, 1 H), 7.21 (s, 2 H), 6.94 (s, 1 H), 6.64 (s, 2 H), 5.72 (d, J = 21.0 Hz, 2 H), 4.64 (d, J = 15 Hz, 2 H), 4.00 (s, 2 H), 3.15 (m, 1 H), 1.25 (m, 18 H), 1.11 (d, J = 4.5 Hz, 6 H); LC-MS m/z = 633 $[C_{29}H_{39}O_9Cl_2P + H]^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (3:2); R_f = 0.62. Anal. Calcd for ($C_{29}H_{39}O_9Cl_2P$ + 0.3 H_2O + 0.2 $CH_3CO_2CH_2CH_3$): C, 54.49; H, 6.32. Found: C, 54.52, H, 6.33;

Compound 12-9: Di(pivaloyloxymethyl [4,6-dichloro-3-fluoro-5-(4'-hydroxy-3'-*iso*-propylphenoxy)-pyrid-2-ylamino]methylphosphonate

The title compound was prepared according to the procedure described for the synthesis of example 12 using [4,6-dichloro-3-fluoro-5-(4'-hydroxy-3'-*iso*-propylphenoxy)-pyrid-2-ylamino]methylphosphonic (US 6747048 B2):

^{1}H NMR (200 MHz, DMSO-d_6): δ 9.20 (s, 1 H), 7.54 (t, J = 6.0 Hz, 1 H), 6.80 (d, J = 3.4 Hz, 1 H), 6.68 (d, J = 8.8 Hz, 1 H), 6.44 (dd, J = 3.4, 8.8 Hz, 1 H), 5.62 (d, J = 12.4 Hz, 4 H), 3.97 (m, 2 H), 3.22 (m, 1 H), 1.07 – 1.17 (m, 24 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (3:2); R_f = 0.51; LC-MS m/z = 654 [C27H36Cl2FN2O9P + H]$^+$; Anal Calcd for (C27H36Cl2FN2O9P + 0.2Et_2OAc): C, 49.76; H, 5.65; N, 4.17. Found: C, 50.02; H, 6.02; N, 4.07.

Example 13

Cis and *Trans* (*S*)-2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenoxy)methyl]-4-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane

To a mixture of [4-(4'-hydroxy-3'-*iso*-propylbenzyl)-3,5-dimethylphenoxy] methylphosphonic acid (0.2 g, 0.55 mmol), 1-(3-chlorophenyl)-1,3-propane diol (0.31 g, 1.6 mmol) and pyridine (1 mL) in DMF (5 mL) at room temperature was added

1,3-dicyclohexylcarbodiimide (0.34 g, 1.6 mmol). The reaction mixture was heated at 70 °C for 4 h, cooled to room temperature and filtered through a Celite plug. The solvent was removed under reduced pressure and the crude product was purified by column chromatography on silica gel, eluting with 4% methanol in CH_2Cl_2 to afford *Cis* (0.06 g, 15%) and *Trans* (*S*)-2-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenoxy]methyl-4-(3-chlorophenyl)-2-oxo-1,3,2-dioxaphosphonane (0.05 g, 12%) as white solids.

Compound 13-1-*cis*: mp 77-82 °C; LC-MS m/z = 516 $[C_{28}H_{32}ClO_5P + H]^+$; Anal. Calcd for ($C_{28}H_{32}ClO_5P$+0.2 H_2O): C, 64.85; H, 6.30. Found: C, 64.93; H, 6.65. M.P.: 77-82.0 °C.

Alternative improved method for the preparation of compound: **Compound 13-1-*cis*:** *Cis* (*S*)-2-[(3,5-Dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy)methyl]-4-(3-Chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphinane:

A solution of *cis* (*S*)-2-[(4-(4'-acetoxy-3'-*iso*-propylbenzyl)-3,5-dimethylphenoxy)methyl]-4-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane (compound 59-cis, 2.5 g, 4.49 mmol) and 4.0 M HCl in dioxane (2.5 mL, 10.0 mmol) in methanol (25 mL) was stirred at 20 °C for 3.5 hrs. The solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-dichloromethane (1:4) to afford *cis* (*S*)-2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy)methyl]-4-(3-Chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphinane (1.9g, 83%): ^1H NMR (300 MHz, DMSO-d_6): δ 8.97 (s, 1H), 7.47 (m, 1H), 7.38-7.31 (m, 3H), 6.82 (d, J = 2.1 Hz, 1H), 6.73 (s, 2H), 6.59 (d, J = 8.1 Hz, 1H), 6.43 (dd, J = 8.1 and 2.0 Hz, 1H), 5.76-5.71 (m, 1H), 4.61-4.36 (m, 4H), 3.78 (s, 2H), 3.15-3.05 (m, 1H), 2.24-2.17 (m, 2H), 2.14 (s, 6H), 1.07 (d, J = 6.9 Hz, 6H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = dichloromethane-acetone (9:1); R_f = 0.28; Anal Calcd for ($C_{28}H_{32}ClO_5P$ + 0.2 H_2O): C, 64.85; H, 6.30. Found: C, 64.64; H, 6.36. Water by KF titration = 0.66%.

Compound 13-1-*trans*: mp 88-93 °C; LC-MS m/z = 516 $[C_{28}H_{32}ClO_5P + H]^+$; Anal. Calcd for ($C_{28}H_{32}ClO_5P$+0.2 H_2O): C, 64.85; H, 6.30. Found: C, 64.93; H, 6.65. M.P.: 88-93.0 °C.

Using the appropriate starting material, compounds 13-2 to 13-14 were prepared in an analogous manner to that described for the synthesis of compound 13-1.

Cis and *Trans* 2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenoxy)methyl]-4-(3-bromophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane:

Compound 13-2-*cis*: mp 70-75 °C; LC-MS *m/z* = 559,561 [$C_{28}H_{32}BrO_5P + H]^+$; Anal. Calcd for ($C_{28}H_{32}BrO_5P$): C, 60.12; H, 5.77. Found: C, 60.03, H, 5.76; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = 3:2 hexanes-acetone; rf = 0.31.

Compound 13-2-*trans*: mp 80-85 °C; LC-MS *m/z* = 559,561 [$C_{28}H_{32}BrO_5P + H]^+$; Anal. Calcd for ($C_{28}H_{32}BrO_5P$): C, 60.12; H, 5.77. Found: C, 59.76, H, 5.72; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = 3:2 hexanes-acetone; rf = 0.49.

Cis and *Trans* 2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenoxy)methyl]-4-(3-fluorophenyl)-2-oxo-2 λ^5-[1,3,2]-dioxaphosphonane:

Compound 13-3-*cis*: mp 75-80 °C; LC-MS *m/z* = 499 [$C_{28}H_{32}FO_5P + H]^+$; Anal. Calcd for ($C_{28}H_{32}FO_5P$ + 0.2 EtOAc): C, 67.02; H, 6.56. Found: C, 67.01, H, 6.58; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = 3:2 acetone-hexanes; rf = 0.19.

Compound 13-3-*trans*: mp 80-85 °C; LC-MS *m/z* = 499 [$C_{28}H_{32}FO_5P + H]^+$; Anal. Calcd for ($C_{28}H_{32}FO_5P$ + 0.2 EtOAc): C, 67.02; H, 6.56. Found: C, 66.93, H, 6.61; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = 3:2 acetone-hexanes; rf = 0.52.

Cis and *Trans* 2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy) methyl]-4-(pyrid-3-yl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane:

Compound 13-4-*trans*: mp 75-78 °C: LC-MS *m/z* = 482 [$C_{27}H_{32}NO_5P$+H]$^+$; Anal Calcd for $C_{27}H_{32}NO_5P$: C, 67.35; H, 6.70; N, 2.91. Found: C, 67.17; H, 6.89; N, 2.62; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = CH_2Cl_2-MeOH (2%); R_f = 0.3.

Compound 13-4-*cis*: (108 mg, 50%): mp 75-78 °C; LC-MS $m/z = 482$ $[C_{27}H_{32}NO_5P+H]^+$; Anal Calcd for $C_{27}H_{32}NO_5P$: C, 67.35; H, 6.70, N, 2.91. Found: C, 67.78; H, 6.76; N, 2.63; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = CH_2Cl_2-MeOH (2%); $R_f = 0.27$.

Cis and *Trans* 2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy) methyl]-4-(pyrid-4-yl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane:

Compound 13-5-*trans*: (52%), mp 75-77 °C; LC-MS $m/z = 482$ $[C_{27}H_{32}NO_5P+H]^+$; Anal Calcd for ($C_{27}H_{32}NO_5P$+0.4 H_2O): C, 66.35; H, 6.76; N, 2.87. Found: C, 66.08; H, 6.55; N, 2.74; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = CH_2Cl_2-MeOH (2%); $R_f = 0.3$.

Compound 13-5-*cis*: (20%), mp 75-77 °C; LC-MS $m/z = 482$ $[C_{27}H_{32}NO_5P+H]^+$; Anal Calcd: (MF:$C_{27}H_{32}NO_5P$) Calcd: C:67.35, H:6.70, N:2.91; Found: C: 67.02, H:6.78, N:2.81; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = CH_2Cl_2-MeOH (2%); $R_f = 0.25$.

Cis and *Trans* 2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy) methyl]-4-(4-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane:

Compound 13-6-*trans*: mp 77-80 °C; LC-MS $m/z = 515$ $[C_{28}H_{32}ClO_5P]^+$; Anal Calcd: (MF:$C_{28}H_{32}ClO_5P$+0.1 H_2O+0.4 EtOAc) Calcd: C:64.34, H:6.48; Found: C: 64.56, H:6.91; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = ethyl acetate/hexanes (3:2); $R_f = 0.6$.

Compound 13-6-*cis*: yellow solid, mp 77-80 °C; LC-MS $m/z = 515$ $[C_{28}H_{32}ClO_5P+H]^+$; Anal Calcd: (MF:$C_{28}H_{32}ClO_5P$+0.1 H_2O+0.1 CH_2Cl_2) Calcd: C:64.65, H:6.25; Found: C:64.61, H:6.66; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = ethyl acetate/hexanes (3:2); $R_f = 0.5$.

Cis and *Trans* 2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy) methyl]-4-(3,5-dichlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane:

Compound 13-7-*trans*: mp 79-81 °C; LC-MS m/z = 549 [$C_{27}H_{32}Cl_2O_5P$+H]$^+$; Anal Calcd for ($C_{28}H_{31}Cl_2O_5P$+0.35 H_2O): C, 60.45; H, 5.74; Cl, 12.87. Found: C, 60.15; H, 5.67, Cl, 11.97; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = ethyl acetate/hexanes (3:2); R_f = 0.6.

Compound 13-7-*cis*: (50%), mp 79 - 81 °C; LC-MS m/z = 549 [$C_{28}H_{31}Cl_2O_5P$]$^+$; Anal Calcd for ($C_{28}H_{31}Cl_2O_5P$+0.1 H_2O): C, 60.94; H, 5.70; Cl, 12.97. Found: C, 60.77; H, 6.18; Cl, 11.56; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = ethyl acetate-hexanes (3:2); R_f = 0.5.

Compound 13-8: *Cis*-(*S*)-2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*sec*-butylbenzyl) phenoxy)methyl]-4-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane: mp: 66-70 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.91 (s, 1 H), 7.39-7.36 (m, 3H), 6.76 (s, 1H), 6.75 (s, 2H), 6.60-5.57 (d, 1H), 6.47-6.44 (d, 1H), 5.75-5.71 (m, 1H), 4.61-4.53 (m, 2H), 4.47-4.36 (m, 2H), 3.78 (s, 2H), 2.92-2.85 (q, 1H), 2.25-2.20 (m, 2H), 2.14 (s, 6H), 1.51-1.36 (m, 2H), 1.05-1.03 (d, 3H), 0.74-0.70 (t, 3H); LC-MS m/z = 529.0 [$C_{29}H_{34}ClO_5P$ + H]$^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (1:1); R_f = 0.17; Anal. Calcd for ($C_{29}H_{34}ClO_5P$ + 0.3 $CH_3CO_2CH_2CH_3$ + 0.4 H_2O): C, 64.47; H, 6.66. Found: C, 64.64; H, 6.82.

Compound 13-9: *Cis*-(*S*)-2-[3,5-dibromo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzyl]-4-(3-chlorophenyl)-2-oxo2λ^5-[1,3,2]-dioxaphosphonane: mp: 83-85 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.06 (s, 1H), 7.75 (s, 2H), 7.44-7.42 (m, 3H), 7.32-7.28 (m, 1H), 6.68-6.65(d, 1H), 6.58 (s, 1H), 6.31-6.27 (d, 1H), 5.69-5.65 (d, 1H), 4.59-4.51 (t, 1H), 4.37-4.28 (t, 1H), 3.61-3.53 (d, 2H), 3.18-3.07 (m, 1H), 2.29-2.17 (m, 1H), 1.84-1.77 (m, 1H), 1.07-1.03 (d, 6H); LC-MS m/z = 630.8 [$C_{25}H_{24}Br_2ClO_5P$ + H]$^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (1:1); R_f = 0.56; Anal. Calcd for ($C_{25}H_{24}Br_2ClO_5P$): C, 47.61; H, 3.84. Found: C, 47.88; H, 4.23.

<u>**Compound 13-10**: *Cis* (*S*)-2-[(3,5-diiodo-4-(4'-hydroxy-3'-*iso*-propylphenoxy) phenoxy)methyl]-4-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane</u>

mp: 82-86 °C; ^{1}H NMR (300 MHz, DMSO-d_6): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.99 (s, 1 H), 7.62 (s, 1 H), 7.51 (m, 1 H), 7.44 (s, 2 H), 7.38 (m, 3 H), 6.68 (m, 1 H), 6.60 (s, 1 H), 6.25 (m, 1 H), 5.80 (m, 1 H), 4.65 (m, 3 H), 4.45 (m, 1 H), 3.16 (m, 1 H), 2.26 (m, 1 H), 1.13 (d, J = 6.0 Hz, 6 H); LC-MS m/z = 741 [$C_{25}H_{24}ClI_2O_6P$ + H]$^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (4:1); R_f = 0.17. Anal. Calcd for ($C_{25}H_{24}ClI_2O_6P$ + 0.2 $CH_3CO_2CH_2CH_3$): C, 40.86; H, 3.40. Found: C, 41.02, H, 3.49.

<u>**Compound 13-11**: *Cis* (*S*)-2-[(3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenoxy)methyl]-4-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane</u>

^{1}H NMR (300 MHz, DMSO-d_6): δ 9.10 (s, 1 H), 7.43 (s, 1 H), 7.38-7.31 (m, 4 H), 7.24 (m, 1 H), 6.97 (s, 1 H), 6.64 (s, 2 H), 5.75 (m, 1 H), 4.69-4.61 (m, 2 H), 4.50-4.41 (m, 2 H), 4.05 (s, 2 H), 3.12 (m, 1 H), 2.21 (s, 2 H), 1.11 (d, J = 9.0 Hz, 6 H); LC-MS m/z = 554 [$C_{26}H_{26}Cl_3O_5P$ + H]$^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (4:1); R_f = 0.24. Anal. Calcd for ($C_{26}H_{26}Cl_3O_5P$ + 0.5 H_2O + 0.2 $CH_3CO_2CH_2CH_3$): C, 55.27; H, 4.95. Found: C, 55.21, H, 4.96.

<u>*Cis* and *Trans* 2-[4,6-dichloro-3-fluoro-5-(4'-hydroxy-3'-*iso*-propylphenoxy)-pyrid-2-ylaminomethyl]-4-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane</u>

To a stirring solution of [4,6-dichloro-3-fluoro-5-(4'-hydroxy-3'-*iso*-propylphenoxy)-pyrid-2-ylamino]methylphosphonic (0.2 g, 0.47 mmol, US 6747048 B2) and (S)-1-(3-chlorophenyl)-1,3-propanediol (0.18 g, 0.94 mmol) in DMF (6 mL) at room temperature was add pyridine (0.46 mL, 5.64 mmol) and EDCI (0.27 g, 1.41 mmol). The reaction mixture was stirred at 68 °C for 16 hrs. The solvent was removed under reduced pressure, and the residue was partitioned between EtOAc and water. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate to afford:

<u>**Compound 13-12-*trans*:**</u> (60 mg, 22%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.20 (s, 1 H), 7.67 (t, J = 6.0 Hz, 1 H), 7.36-7.48 (m, 4 H), 6.81 (d, J = 3.0 Hz, 1 H), 6.69 (d, J = 9.0 Hz, 1 H), 6.44 (dd, J = 3.0, 9.0 Hz, 1 H), 5.78 (t, J = 7.5 Hz, 1 H), 4.71 (m, 1 H), 4.45 (m, 1 H), 4.11 (m, 2 H), 3.17 (m, 1 H), 2.19 (s, 1 H), 1.14 (d, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:1); R_f = 0.44; LC-MS m/z = 576 [$C_{24}H_{23}Cl_3FN_2O_5P$ + H]$^+$; Anal Calcd for ($C_{24}H_{23}Cl_3FN_2O_5P$ + $0.2CH_2Cl_2$ + $0.3H_2O$): C, 48.58; H, 4.04; N, 4.68. Found: C, 48.64; H, 3.66; N, 4.83.

<u>**Compound 13-12-*cis*:**</u> (90 mg, 33%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.20 (s, 1 H), 7.67 (t, J = 6.0 Hz, 1 H), 7.21-7.37 (m, 4 H), 6.71 (d, J = 3.0 Hz, 1 H), 6.63 (d, J = 9.0 Hz, 1 H), 6.34 (dd, J = 3.0, 9.0 Hz, 1 H), 5.65 (d, J = 10.4 Hz, 1 H), 4.21 – 4.61 (m, 2 H), 4.11 (m, 1 H), 3.80 (m, 1 H), 3.07 (m, 1 H), 2.11 (m, 1 H), 1.88 (m, 1 H), 1.04 (m, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate; R_f = 0.53; LC-MS m/z = 576 [$C_{24}H_{23}Cl_3FN_2O_5P$ + H]$^+$; Anal Calcd for ($C_{24}H_{23}Cl_3FN_2O_5P$ + $0.1CH_2Cl_2$ + $0.4H_2O$): C, 48.94; H, 4.09; N, 4.74. Found: C, 48.57; H, 3.69; N, 4.92.

<u>*Cis* and *trans* 2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenoxy)methyl]-4,4-dimethyl-6-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane:</u>

<u>Preparation of 1-(3-Chloro-phenyl)-3-methyl-butane-1,3-diol:</u>

Step a:

To a solution of diisopropyl amine (12.4 mL, 88.2 mmol) in THF (50 mL) at –78 °C was added n-butyllithium (35.3 mL, 88.2 mmol). The reaction mixture was stirred at –78 °C for 30 min, at which time ethyl acetate was added (16.1 mL, 163.2 mmol). After 1 h, 3-chloro benzaldehyde was added and the reaction mixture was allowed to warm to room temperature over 2h. The reaction mixture was quenched with aqueous saturated NH_4Cl (20 mL) and extracted with ethyl acetate (2 x 20mL). The organic layer was rinsed with water (20 mL) and brine (20 mL), dried over Na2SO4, filtered and concentrated under reduced pressure to afford yellow oil. The crude product was purified by column chromatography on silica gel, eluted with ethyl acetate-hexanes (1:4) to afford ethyl 3-(3-chloro-phenyl)-3-hydroxy-propionate as a yellow oil (10.0 g, 99.0 %). ^{1}H NMR (400 MHz, d-DMSO): δ 7.43-7.30 (m, 4H), 5.66 (d, 1H), 5.01-4.95 (q,

1H), 4.14-4.04 (m, 2H), 2.71-2.58 (m, 2H), 1.24-1.17 (t, 3H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:3); R_f = 0.50.

Step b:

To a solution of ethyl 3-(3-chloro-phenyl)-3-hydroxy-propionate (10.0g, 44.1 mmol) in THF (100 mL) and diethyl ether (100 mL) at –78°C was added methyl magnesium bromide (61.7 mL of a 3.0M solution in diethyl ether, 185.1 mmol). The reaction mixture was allowed to warm to room temperature and stir for 16 h. The reaction mixture was cooled to –50°C and quenched with aqueous saturated NH_4Cl (20mL), and extracted with diethyl ether (2 x 20 mL). The organic layer was rinsed with water (20 mL) and brine (20 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluted with ethyl acetate-hexanes (1:3) to afford 1-(3-Chloro-phenyl)-3-methyl-butane-1,3-diol as a yellow oil (5.65 g, 59.7 %). ^{1}H NMR (400 MHz, d-DMSO): δ 7.40-7.26 (m, 4H), 5.46 (d, 1H), 4.90-4.85 (q, 1H), 4.70 (s, 1H), 1.75-1.62 (m, 2H), 1.23-1.22 (d, 3H), 1.19-1.18 (d, 3H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:3); R_f = 0.32.

Compound 13-13-*cis*: *Cis* 2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenoxy)methyl]-4,4-dimethyl-6-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane:

^{1}H NMR (400 MHz, d-DMSO): δ 9.05 (s, 1 H), 7.59 (s, 1H), 7.47-7.43 (m, 3H), 6.91 (s, 1H), 6.81 (s, 2H), 6.68-6.65 (d, 1H), 6.53-6.50 (d, 1H), 5.92-5.87 (t, 1H), 4.54-4.40 (m, 2H), 3.87 (s, 2H), 3.23-3.14 (q, 1H), 2.55-2.23 (m, 8H), 1.69 (s, 3H), 1.44 (s, 3H), 1.17-1.14 (d, 6H); LC-MS *m/z* = 544.8 $[C_{30}H_{36}ClO_5P + H]^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (1:1); R_f = 0.16; Anal. Calcd for ($C_{30}H_{36}ClO_5P$ + 1.0 $CH_3CO_2CH_2CH_3$): C, 64.70; H, 7.03; Found: C, 64.50; H, 7.32.

Compound 13-13-*trans*: *Trans* 2-[(3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenoxy)methyl]-4,4-dimethyl-6-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane:

LC-MS *m/z* = 544.8 $[C_{30}H_{36}ClO_5P + H]^+$; ^{1}H NMR (400 MHz, d-DMSO): δ 9.00 (s, 1 H), 7.54 (s, 1H), 7.49-7.44 (m, 3H), 6.86 (s, 1H), 6.79 (s, 2H), 6.63-6.60 (d, 1H), 6.46-6.43 (d, 1H), 5.85-5.82 (t, 1H), 4.46-4.43 (d, 2H), 3.82 (s, 2H), 3.16-3.11 (q, 1H), 2.28-

2.25 (d, 2H), 2.18 (s, 6H), 1.62 (s, 3H), 1.47 (s, 3H), 1.12-1.10 (d, 6H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (1:1); R_f = 0.27; Anal. Calcd for ($C_{30}H_{36}ClO_5P$ + 1.4 $CH_3CO_2CH_2CH_3$): C, 64.17; H, 7.14; Found: C, 64.06; H, 6.98.

Cis and *trans* (*S*) 2-[(3,5-dimethyl-4-(3'-(4-fluorobenzyl)-4'-hydroxybenzyl) phenoxy)methyl]-4-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane]:

Compound 13-14-*cis*: *Cis* (*S*) 2-[(3,5-dimethyl-4-(3'-(4-fluorobenzyl)-4'-hydroxybenzyl) phenoxy)methyl]-4-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane]:

(0.041 g, 14%); ^{1}H NMR (300 MHz, CD_3OD): δ 7.46(s, 1H), 7.28(m, 3H), 7.11-6.91(m, 4H), 6.63(m, 5H), 5.72(d, 1H, J = 11.4 Hz), 4.71(m, 1H), 4.51(m, 3H), 3.84(m, 4H), 2.44(m, 1H), 2.22(m, 1H), 2.15(s, 6H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexane 25% in ethyl acetate; Rf = 0.21; LC-MS m/z = 582 [$C_{32}H_{41}ClFO_5P$ + H]$^+$; Anal Calcd for ($C_{32}H_{41}ClFO_5P$ +0.5 H_2O): C, 65.14; H, 5.47. Found: C, 65.31; H, 5.67.

Compound 13-14-*trans*: *Trans* (*S*) 2-[(3,5-dimethyl-4-(3'-(4-fluorobenzyl)-4'-hydroxybenzyl) phenoxy)methyl]-4-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane]:

(0.030 g, 10%); ^{1}H NMR (300 MHz, CD_3OD): δ 7.46(s, 1H), 7.28(m, 3H), 7.11-6.91(m, 4H), 6.63(m, 5H), 5.86(d, 1H, J = 11.4 Hz), 4.57(m, 4H), 3.84(m, 4H), 2.34(m, 1H), 2.25(m, 1H), 2.15(s, 6H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexane 25% in ethyl acetate; Rf = 0.41; LC-MS m/z = 582 [$C_{32}H_{41}ClFO_5P$ + H]$^+$; Anal Calcd for ($C_{32}H_{41}ClFO_5P$ +0.5 H_2O): C, 65.14; H, 5.47. Found: C, 65.24; H, 5.77.

Example 14

Compound 14: di(*S*-acetyl-2-thioethyl) [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)]phenoxy]methylphosphonate

A mixture of *S*-acetyl-2-thioethanol (0.12 g, 0.96 mmol), [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid (0.10 g, 0.25 mmol), pyridine (1.0 mL) and dicyclohexylcarbodiimide (0.14 g, 0.69 mmol) in DMF (2.5 mL) was heated at 70 °C for 16h. The reaction mixture was cooled to room temperature and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford di(*S*-acyl-2-thioethyl) [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy] methylphosphonate as an oil (0.09 g, 56%): LC-MS *m/z* = 569 [$C_{27}H_{37}O_7PS_2$ + H]$^+$; Anal. Calcd for ($C_{27}H_{37}O_7PS_2$): C, 57.03; H, 6.56. Found: C, 57.02, H, 7.03; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = 2/3 hexanes/EtOAc; phosphonic acid rf = 0.00, rf = 0.35.

Example 15

Compound 15-1: di-*N*-(*l*-1-ethoxycarbonylethylamino) [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)]phenoxy]methylphosphonamide

To a stirred solution of [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)] phenoxymethyl) phosphonic acid (1, 0.3 g, 0.8 mmol) and DMF(0.1 mL, 0.08 mmol) in 1,2 dichloroethane (10 mL) at room temperature was added oxalylchloride (0.55 g, 2.8 mmol). The reaction mixture was heated at 50 °C for 3 h, cooled to room temperature and concentrated under reduced pressure. To the residue at 0 °C was added a solution of alanine ethylester (0.57 g, 4.3 mmol) and *N,N*-diispropylethylamine(0.6 mL, 4.3 mmol) in CH_2Cl_2. The reaction mixture was stirred for 14 h at room temperature and concentrated under reduced pressure. The residue was partitioned between EtOAc (50 mL) and aqueous $NaHCO_3$ solution (100 mL). The organic layer was separated, washed with brine, dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with CH_2Cl_2-MeOH (95:5) to afford Di(ethoxycarbonyl-1-ethylamino) [3,5-Dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)]phenoxy]methylphosphonamide as a yellow solid (175 mg, 52%): mp 48-50 °C; LC-MS *m/z* = 563 [$C_{29}H_{43}N_2O_7P$+H]$^+$; Anal

Calcd for: ($C_{29}H_{43}N_2O_7P$+0.2 CH_2Cl_2): C, 60.24; H, 7.52; N, 4.80. Found: C, 59.86; H, 8.01; N, 5.12.

Using the appropriate starting material, compounds 15-2 to 15-9 were prepared in an analogous manner to that described for the synthesis of compound 15-1.

Compound 15-2: di-*N*-(1-ethoxycarbonyl-1-methylethylamino) [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)]phenoxy]methylphosphonamide:

LC-MS m/z = 591 [$C_{29}H_{43}N_2O_7P$+H]$^+$; Anal Calcd for ($C_{29}H_{43}N_2O_7P$+0.2 CH_2Cl_2): C, 60.24; H, 7.52; N, 4.80. Found: C, 59.86; H, 8.01; N, 5.12; TLC conditions: Uniplate silica gel, 250 microns; mobile phase = ethyl acetate/ hexanes (4:1); R_f = 0.4.

Using the appropriate starting material, compound 15-3 was prepared in an analogous manner to that described for the synthesis of compound 15-1.

Compound 15-3: di-*N*-(1-ethoxycarbonyl-2-methyl-propylamino) [3,5-dimethyl-4-(3'-*iso*-propyl-4'-hydroxybenzyl)phenoxy]methylphosphonamide

mp: 52-55 °C; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (3:1); R_f= 0.4; ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.84 (d, J= 2.1 Hz, 1 H), 6.52 (d, J= 7.2 Hz, 1 H), 6.42 (dd, J= 1.8, 4.5 Hz, 1 H), 4.02-4.20 (m, 6 H), 3.70-3.95 (m, 2 H), 3.80 (s, 2 H), 3.05-3.35 (m, 3 H), 2.13 (s, 6 H), 1.09-1.20 (m, 9 H), 0.95 (t, J= 6.9 Hz, 3 H), 0.81 (dd, J= 2.1, 6.9 Hz, 6 H),; LC-MS m/z = 619 [$C_{33}H_{51}N_2O_7P$ + H]$^+$; Anal Calcd for: ($C_{33}H_{51}N_2O_7P$ + 0.75 H_2O): C, 62.29; H, 8.37; N, 4.43. Found: C, 62.48; H, 8.89; N, 4.37.

Compound 15-4: di-*N*-(L-1-ethoxycarbonylethylamino) [3,5-dimethyl-4-(4'-hydroxy-3'-*sec*-butylbenzyl)phenoxy]methylphosphonamide:

^{1}H NMR (300 MHz, DMSO-d_6): δ 8.94 (s, 1H), 6.77 (s, 1H), 6.64-6.61 (m, 3H), 6.51-6.48 (d, 1H), 4.87-4.75 (q, 2H), 4.09-3.99 (m, 4H), 3.81 (s, 2H), 2.95-2.88 (q, 1H), 2.17 (s, 6H), 1.57-1.37 (m, 2H), 1.31-1.29 (d, 6H), 1.26-1.16 (m, 4H), 1.08-1.06 (d, 3H), 0.78-0.73 (t, 3H); LC-MS m/z = 577.6 [$C_{30}H_{45}N_2O_7P$ + H]$^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (1:1); R_f = 0.58; Anal. Calcd for ($C_{30}H_{45}N_2O_7P$ + 1.1 H_2O): C, 60.41; H, 7.98; N, 4.70. Found: C, 60.12; H, 7.58; N, 4.49.

Compound 15-5: di-*N*-(L-1-ethoxycarbonylethylamino) [3,5-dibromo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzyl]phosphonamide:

^{1}H NMR (300 MHz, DMSO-d_6): δ 9.08 (s, 1H), 7.68 (s, 2H), 6.69-6.66 (d, 1H), 6.63 (s, 1H), 6.31-6.28 (d, 1H), 4.76-4.61 (q, 2H), 4.09-4.01 (m, 8H), 3.17-3.08 (q, 1H), 1.27-1.10 (m, 18H); LC-MS *m/z* = 679.4 [$C_{26}H_{35}Br_2N_2O_7P$ + H]$^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = dichloromethane-ethyl acetate (1:1); R_f = 0.34; Anal. Calcd for ($C_{26}H_{35}Br_2N_2O_7P$ + 0.6 CF_3CO_2H): C, 43.92; H, 4.84; N, 3.78. Found: C, 43.51; H, 4.78; N, 4.26.

Compound 15-6: di-*N*-(L-1-ethoxycarbonylethylamino) [4,6-dichloro-3-fluoro-5-(4'-hydroxy-3'-*iso*-propylphenoxy)-pyrid-2-ylamino]methylphosphonnamide

To a stirring suspension of [4,6-dichloro-3-fluoro-5-(4'-hydroxy-3'-*iso*-propylphenoxy)-pyrid-2-ylamino]methylphosphonic (0.11 g, 0.26 mmol, US 6747048 B2) and L-alanine (0.16 g, 10.4 mmol) at room temperature in pyridine (2 mL) was added TEA (0.14 mL, 1.04 mmol), followed by a fresh prepared a solution of aldrithio-2 (0.25 g, 1.12 mmol) and PPh_3 (0.29 g, 1.12 mmol) in pyridine (2 mL). The reaction mixture was stirred at 85 °C for 16 hrs. The solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate to afford the title compound as a yellow foam (40 mg, 25%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.20 (s, 1 H), 6.99 (t, J = 6.0 Hz, 1 H), 6.78 (d, J = 3.0 Hz, 1 H), 6.68 (d, J = 9.0 Hz, 1 H), 6.46 (dd, J = 3.0, 9.0 Hz, 1 H), 4.86 (m, 1 H), 4.66 (m, 1 H), 4.07 (m, 4 H), 3.83 (m, 2 H), 3.44 (m, 2 H), 3.16 (m, 1 H), 1.11 – 1.27 (m, 18 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate; R_f = 0.54; LC-MS *m/z* = 624 [C25H34Cl2FN4O7P + H]$^+$; Anal Calcd for (C25H34Cl2FN4O7P): C, 48.16; H, 5.50; N, 8.99. Found: C, 47.99; H, 5.26; N, 8.77.

Compound 15-7: Di-*N*-(*l*-1-ethoxycarbonylethylamino) [3,5-dichloro-4-(4'-hydroxy-3'-*iso*- propylbenzyl)]phenoxy]methylphosphonamide

^{1}H NMR (300 MHz, DMSO-d_6): δ 9.11 (s, 1 H), 7.12 (s, 2 H), 6.97 (m, 1 H), 6.66 (m, 2 H), 4.89 (m, 2 H), 4.22 (m, 2 H), 4.05-3.93 (m, 8 H), 3.14 (m, 1 H), 1.28 (m, 6 H), 1.16 (m, 12 H); LC-MS *m/z* = 603 [$C_{27}H_{33}Cl_2N_2O_7P$ + H]$^+$; Anal. Calcd for ($C_{27}H_{33}Cl_2N_2O_7P$ + 0.5 H_2O): C, 52.95; H, 6.25; N, 4.57. Found: C, 52.97; H, 6.32; N, 4.71; TLC

conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (4:1); $R_f = 0.26$.

<u>**Compound 15-8**: Di-*N*-(*l*-1-ethoxycarbonylethylamino) [3,5-diiodo-4-(4'-hydroxy-3'-*iso*- propylphenoxy)]phenoxy]methylphosphonamide</u>

^{1}H NMR (300 MHz, DMSO-d_6): δ 8.99 (s, 1 H), 7.50 (s, 2 H), 6.68 (m, 1 H), 6.56 (m, 1 H), 6.25 (m, 1 H), 4.87 (m, 2 H), 4.18 (m, 2 H), 4.06-3.95 (m, 6 H), 3.17 (m, 1 H), 1.32 (m, 6 H), 1.21-1.11 (m, 12 H); LC-MS *m/z* = 789 $[C_{26}H_{35}I_2N_2O_8P + H]^+$; Anal. Calcd for ($C_{26}H_{35}I_2N_2O_8P + 0.1\ H_2O$): C, 39.52; H, 4.49; N, 3.55. Found: C, 39.49; H, 4.50; N, 3.46; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (1:1); $R_f = 0.13$.

<u>**Compound 15-9**: Di-*N*-(*l*-1-ethoxycarbonylethylamino) [3,5-dimethyl-4-(3'-(4-fluorobenzyl)-4'-hydroxybenzyl)]phenoxy]methylphosphonamide</u>

^{1}H NMR (300 MHz, CD_3OD): δ 7.12(m, 2H), 7.89(m, 2H), 6.61(m, 5H), 4.19(dd, 2H, J = 2.4 Hz and J = 14 Hz), 4.08(m, 5H), 3.84(s, 2H), 3.81(s, 2H), 2.15(s, 6H), 2.25(m, 1H), 2.15(s, 6H), 1.40(d, 6H, J = 7.5 Hz), 1.21(m, 6H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate; Rf = 0.18; LC-MS *m/z* = 629 $[C_{33}H_{42}FN_2O_7P + H]^+$, Anal Calcd for ($C_{33}H_{42}FN_2O_7P + 1.1\ H_2O$): C, 61.12; H, 6.87, N, 4.32. Found: C, 60.85; H, 6.78, N, 4.72.

<u>**Example 16**</u>

<u>**Compound 16:** 3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzylphosphonic acid</u>

Step a:

To a solution of 3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzyl alcohol in CH_2Cl_2 (5.0 mL) at -78 °C is added BBr_3. The reaction mixture is stirred at room temperature for 16 h, poured into ice water and extracted with ethyl acetate. The organic layer is dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product is purified by column chromatography on silica gel, eluting with

acetone-hexanes to afford 3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzyl bromide.

Step b:

Diethyl 3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzylphosphonate is prepared from 3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzyl bromide by following the procedure described in example 9, step g.

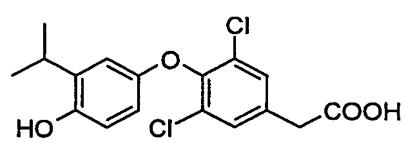
Step c:

3,5-Dichloro-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzylphosphonic acid is prepared from diethyl 3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzylphosphonate by following the procedure described in example 9, step h.

Compound 17: [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]acetic acid

Compound 17 was synthesized by a literature method (G. Chiellini *et al. Bioorg. Med. Chem. Lett.* **2000,** *10,* 2607)

Compound 18: 3,5-dichloro-4-[4'-hydroxy-3'-*iso*-propyl phenoxy]benzeneacetic acid



Example 19

Compound 19: [3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylphenoxy)]benzylphosphonic acid

Step a:

To a mixture of bis(4-methoxy-3-*iso*-propylphenyl)iodonium tetrafluoroborate (4.55 g, 8.88 mmol) and copper powder (0.88 g, 13.80 mmol) in CH_2Cl_2 (40.0 mL) at 0 °C was added a solution of TEA (1.06 mL, 3.71 mmol) and methyl 3,5-dichloro-4-hydroxybenzoate (1.65 g, 6.90 mmol) in dichloromethane (20.0 mL). The reaction mixture was stirred at room temperature for 3 d and filtered through a Celite plug. The

solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:19) to afford methyl 3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzoate as an orange oil (2.02 g, 80%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.10 (m, 1 H), 6.85 (m, 2 H), 6.50 (m, 1 H), 3.90 (s, 3 H), 3.76 (s, 3H), 3.21 (m, 1 H), 1.14 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (17:3); R_f = 0.51.

Step b:

To a mixture of methyl 3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)-benzoate (1.40 g, 3.37 mmol) in THF (10.0 mL) at 0 °C was added a solution of DIBAL-H (8.12 mL, 8.12 mmol, 1.0 M solution in THF). The reaction mixture was stirred at room temperature for 16 h, quenched with cold 1 N HCl and diluted with ethyl acetate. The organic layer was washed with 1 N HCl and brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure to afford 4-(3'-*iso*-propyl-4'-methoxyphenoxy)-3,5-dichlorobenzyl alcohol as an off-white solid (0.94 g, 100%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.54 (s, 2 H), 6.81 (m, 2 H), 6.40 (m, 1 H), 5.51 (m, 1 H), 4.54 (d, J = 6.0 Hz, 2 H), 3.75 (s, 3 H), 3.21 (m, 1 H), 1.13 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (17:3); R_f = 0.27.

Step c:

To a stirred solution of triphenylphosphine (0.42 g, 1.61 mmol) and CBr_4 (0.534 g, 1.61 mmol) in diethyl ether (15.0 mL) at room temperature was added 4-(3'-*iso*-propyl-4'-methoxyphenoxy)-3,5-dichlorobenzyl alcohol (0.50 g, 1.46 mmol). The reaction mixture was stirred at room temperature for 16 h, filtered and concentrated under reduced pressure.The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:9) to afford 3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzyl bromide (0.320 g, 54%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.77 (s, 2 H), 6.82 (m, 2 H), 6.38 (m, 1 H), 4.75 (s, 2 H), 3.75 (s, 3 H), 3.22 (m, 1 H), 1.13 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (1:4); R_f = 0.46.

Step d:

A mixture of 3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzyl bromide (0.61 g, 1.51 mmol) and triethylphosphite (0.61 g, 3.56 mmol) in DMF (2.0 mL) was heated under reflux for 4 h. The reaction mixture was cooled to room temperature, diluted with ethyl acetate, and washed with water and brine. The organic layer was concentrated under reduced pressure and the residue was purified by column

chromatography on silica gel, eluting with acetone-hexanes (3:7) to afford diethyl 3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzylphosphonate as an oil (0.59 g, 85%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.55 (s, 2 H), 6.88 (d, J = 9.0 Hz, 1 H), 6.75 (d, J = 3.0 Hz, 1 H), 6.43 (m, 1 H), 4.01 (m, 4 H), 3.75 (s, 3 H), 3.41 (m, 2 H), 3.22 (m, 1 H), 1.20 (m, 6 H), 1.12 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (4:1); R_f = 0.22.

Step e:

To a solution of diethyl 3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzylphosphonate (0.59 g, 1.28 mmol) in CH_2Cl_2 (10.0 mL) at -30 °C was added bromotrimethylsilane (2.53 mL, 19.2 mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was dissolved in dichloromethane (25.0 mL), cooled to –78 °C and to it was added BBr_3 (19.0 mL, 19.0 mmol, 1.0 M solution in CH_2Cl_2). The reaction mixture was stirred at -78 °C for 10 min, allowed to warm to room temperature and stirred for 16 h. The reaction mixture was poured into ice, concentrated and extracted with ethyl acetate. The organic layer was washed with water (20 mLx2), dried over $MgSO_4$ and filtered. The solvent was removed under reduced pressure to afford 3,5-dichloro-4-(3'-*iso*-propyl-4'-hydroxyphenoxy)benzylphosphonic acid as a brown solid (0.20 g, 40%): mp: 178-181 °C; LC-MS m/z = 391 [$C_{16}H_{17}Cl_2O_5P$ - H]$^-$; ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.08 (s, 1 H), 7.48 (s, 2 H), 6.72 (m, 2 H), 6.25 (m, 1 H), 3.18 (m, 1 H), 3.00 (d, J = 21.0 Hz, 2 H), 3.11 (m, 1 H), 1.14 (d, J = 6.0 Hz, 6 H); Anal. Calcd for ($C_{16}H_{17}Cl_2O_5P$ + 0.2 $C_4H_8O_2$ + 0.5 H_2O): C, 48.30; H, 4.73. Found: C, 48.69, H, 5.16.

Using the appropriate starting material, compounds19-1 to 19-3 was prepared in an analogous manner to that described for the synthesis of compound 19.

Compound 19-1: diethyl [3,5-dibromo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)]benzylphosphonate

Prepared from methyl 3,5-dibromo-4-hydroxybenzoate (*J. Med. Chem.* **2003**, *46*, 1580) according to the procedure described for the synthesis of compound 19. mp: 145 °C; LC-MS m/z = 536 [$C_{20}H_{25}Br_2O_5P$ + H]$^+$; ^{1}H NMR (300 MHz, CD_3OD): δ 7.53 (s, 2 H), 6.50 (m, 2 H), 6.23 (m, 1 H), 3.98 (m, 4 H), 3.11 (m, 1 H), 1.21 (m, 6 H), 1.02 (d, J = 6.0 Hz, 6 H); Anal. Calcd for ($C_{20}H_{25}Br_2O_5P$): C, 44.80; H, 4.70. Found: C, 45.19, H, 4.80.

Compound 19-2: [3,5-dibromo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)]benzylphosphonic Acid

Prepared from compound 19-1 according to the procedure described for the synthesis of compound 19 step e.

mp: 76-79 °C; LC-MS *m/z* = 480 [$C_{16}H_{17}Br_2O_5P + H]^+$; ^{1}H NMR (300 MHz, CD_3OD): δ 7.52 (s, 2 H), 6.55 (m, 2 H), 6.20 (m, 1 H), 3.14 (m, 1 H), 3.00 (d, *J* = 21.0 Hz, 2 H), 1.06 (d, *J* = 6.0 Hz, 6 H); HPLC conditions: Column = 3 Chromolith SpeedRODs RP-18e, 100×4.6 mm; Mobile phase = Solvent A (Acetonitrile) = HPLC grade acetonitrile; Solvent B (buffer) = 20 mM ammonium phosphate buffer (pH 6.1, 0.018 M $NH_4H_2PO_4$/0.002 M $(NH_4)_2HPO_4$) with 5% acetonitrile. Flow rate = 4 mL/min; UV@ 255 nm. Retention time in minutes. (rt = 5.80, 96% purity).

Compound 19-3: [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)]benzylphosphonic acid

Prepared from methyl 3,5-dimethyl-4-hydroxybenzoate according to the procedure described for the synthesis of compound 19.

mp: 79-82 °C; LC-MS *m/z* = 351 [$C_{18}H_{23}O_5P + H]^+$; ^{1}H NMR (300 MHz, CD_3OD): δ 6.93 (s, 2 H), 6.51 (m, 2 H), 6.13 (m, 1 H), 3.13 (m, 1 H), 2.98 (d, *J* = 21.0 Hz, 2 H), 1.96 (s, 6 H), 1.04 (d, *J* = 6.0 Hz, 6 H); Anal. Calcd for ($C_{18}H_{23}O_5P$ + 1.2 H_2O): C, 58.12; H, 6.88. Found: C, 58.01; H, 7.00.

Example 20

Compound 20 [3,5-dimethyl-4-*N*-(4'-hydroxy-3-*iso*-propylphenylamino)phenoxy]methylphosphonic acid

Step a:

A solution of 4-amino-3,5-dimethylphenol (5.0 g, 36.46 mmol, Fieser, L. F. *Organic Syntheses*, Collect Vol II, 1943, 39), imidazole (6.21 g, 77.37 mmol) and triisopropylsilyl chloride (7.70 g, 40.1 mmol) in CH_2Cl_2 (80 mL) was stirred at room temperature for 1 h. The reaction mixture was diluted with CH_2Cl_2 (100.0 mL) and washed with water and brine. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:19) to afford 2,6-

dimethyl-4-triisopropylsilanyloxyphenylamine (8.46 g, 79%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.57 (s, 2 H), 2.19 (s, 6 H), 1.23 (m, 3 H), 1.12 (m, 18 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); R_f = 0.51.

Step b:

A mixture of $Pd_2(dba)_3$ (800 mg, 0.87 mmol) and BINAP (1.09 g, 1.75 mmol) in toluene (70 mL) at 100 °C in a sealed tube was heated for 30 min. The reaction mixture was cooled to room temperature and to it was added 2,6-dimethyl-4-triisopropylsilanyloxyphenylamine (6.15 g, 20.98 mmol) followed by 4-bromo-2-*iso*-propyl-1-methoxymethoxybenzene (4.0 g, 17.48 mmol) and potassium *tert*-butoxide (2.18 g, 22.72 mmol). The reaction mixture was heated at 110 °C in the sealed tube for 16 h, cooled to room temperature and filtered through a plug of Celite. The solvent was removed under reduced pressure and the crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:9) to afford *N, N*-(2,6-dimethyl-4-triisopropylsilanyloxyphenyl)-(3-*iso*-propyl-4-methoxymethoxyphenyl)amine as a yellow solid (4.8 g, 58%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.88 (d, J = 8.7 Hz, 1 H), 6.67 (s, 1 H), 6.41 (d, J = 2.7 Hz, 1 H), 6.22 (m, 1 H), 5.11 (s, 2 H), 3.52 (s, 3 H), 3.28 (m, 1 H), 2.17 (s, 6 H), 1.28 (m, 3 H), 1.15 (m, 24 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); R_f = 0.70.

Step c:

To a solution of *N, N*-(2,6-dimethyl-4-triisopropylsilanyloxyphenyl)-(3-*iso*-propyl-4-methoxymethoxyphenyl)amine (800 mg, 1.70 mmol) in THF (10.0 mL) at 0 °C was added TBAF (2.55 mmol, 1.0 M in THF). The reaction mixture was stirred at room temperature for 16 h, diluted with ethyl acetate (10.0 mL) and quenched with H_2O (10.0 mL). The aqueous layer was extracted with ethyl acetate (10.0 mL) and the combined organic layers were dried over $MgSO_4$. The solvent was removed under reduced pressure and the crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:4) to afford 3,5-dimethyl-4-*N*-(3-*iso*-propyl-4'-methoxymethoxyphenylamino)phenol (280 mg, 52%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.88 (d, J = 8.1 Hz, 1 H), 6.63 (s, 2 H), 6.47 (m, 1 H), 6.21(m, 1 H), 5.12 (s, 2 H), 3.52 (s, 3H), 3.30 (m, 1 H), 2.19 (s, 6 H), 1.2 (d, 6 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); R_f = 0.45.

Step d:

To a solution of sodium hydride (22 mg, 0.86 mmol) in DMF at 0 °C was added a solution of 3,5-dimethyl-4-*N*-(3-*iso*-propyl-4'-methoxymethoxyphenylamino)phenol (270 mg, 0.86 mmol) in DMF (2.0 mL). The reaction mixture was stirred at room temperature for 1 h and to it was added a solution of diethyl tosyloxymethylphosphonate (0.34 g, 1.03 mmol) in DMF (1.0 mL). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was partitioned between ethyl acetate (10.0 mL) and saturated aqueous $NaHCO_3$ (10.0 mL). The organic layer was separated and the aqueous layer was extracted with ethyl acetate (10.0 mL). The combined organic layers were dried over $MgSO_4$, filtrated and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl [3,5-dimethyl-4-*N*-(3-*iso*-propyl-4'-methoxymethoxyphenylamino)phenoxy]methylphosphonate (160 mg, 52%): ^1H NMR (300 MHz, $CDCl_3$): δ 6.88 (d, J = 8.4 Hz, 1 H), 6.75 (s, 2 H), 6.46 (m, 1 H), 6.20 (m, 1 H), 5.12 (s, 2 H), 4.25 (m, 6 H), 3.52 (s, 3 H), 3.28 (m, 1 H), 2.21 (s, 6 H), 1.40 (m, 6 H), 1.20 (d, J = 6.9 Hz, 6 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); R_f = 0.29.

Step e:

To a solution of diethyl [3,5-dimethyl-4-*N*-(3-*iso*-propyl-4'-methoxymethoxyphenylamino)phenoxy]methylphosphonate (150 mg, 0.32 mmol) in CH_2Cl_2 (10 mL) at room temperature was added TMSBr (0.51 mL, 3.88 mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was treated with water (5.0 mL), stirred for 2 h and extracted with ethyl acetate (10.0 mLx2). The combined organic layers were dried over $MgSO_4$, filtrated and concentrated under reduced pressure. The crude product was purified by preparatory LC-MS to afford [3,5-dimethyl-4-*N*-(4'-hydroxy-3-*iso*-propylphenylamino)phenoxy]methylphosphonic acid as a blue solid (40 mg, 33.9%): ^1H NMR (300 MHz, $CDCl_3$): δ 8.3 (s, 1 H), 6.74 (s, 2 H), 6.49 (d, J = 8.4 Hz, 1 H), 6.36 (d, J = 2.4 Hz, 1 H), 5.92 (m, 1 H), 4.05 (d, J = 10.5 Hz, 2 H), 3.11 (m, 1H), 2.10 (s, 6 H), 1.10 (d, J = 6.9 Hz, 6 H). mp > 200 °C; LC-MS m/z = 366 $[C_{18}H_{24}NO_5P + H]^+$; Anal. Calcd for ($C_{18}H_{24}NO_5P$ + 0.5 H_2O + 0.2 HCl): C, 56.65; H, 6.66; N, 3.67. Found: C, 56.45; H, 6.73; N, 3.71.

Using the appropriate starting material, compound 20-1 was prepared in an analogous manner to that described for the synthesis of compound 20.

Compound 20-1 [3,5-dimethyl-4-(4'-hydroxy-3-*iso*-propylphenylmethylamino)phenoxy]methylphosphonic acid

Prepared by standard reductive amination (*J. Org. Chem.* **1972**, *37*, 1673) of *N*, *N*-(2,6-dimethyl-4-triisopropylsilanyloxyphenyl)-(3-*iso*-propyl-4-methoxymethoxyphenyl)amine with formaldehyde followed by the same procedure described for the synthesis compound 20.

^{1}H NMR (300 MHz, $CDCl_3$): δ 8.28 (s, 1 H), 6.76 (s, 2 H), 6.54 (d, J = 8.8 Hz, 1 H), 6.15 (m, 1 H), 5.94 (m, 1 H), 4.05 (d, J = 10.2 Hz, 2 H), 3.13 (m, 1 H), 3.02 (s, 3 H), 1.97 (s, 6 H), 1.06 (d, J = 7.0 Hz, 6 H). mp > 200 °C. LC-MS m/z = 379 [$C_{19}H_{26}NO_5P$ + H]$^-$; Anal. Calcd for ($C_{19}H_{26}NO_5P$ + 0.3 HBr + 0.1 CH_2Cl_2): C, 55.41; H, 6.46; N, 3.38. Found: C, 55.35; H, 6.55; N, 3.43.

Example 21

Compound 21: 2-[3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenyl]-2-oxoethylphosphonic acid

Step a:

To a stirred solution of diethyl methylphosphonate (0.4 g, 2.6 mmol) in anhydrous THF (15 mL) at -78 °C was added *n*-BuLi (1.95 mL, 1.95 mmol, 1 M solution in hexanes). The reaction mixture was stirred at -78 °C for 1 h and to it was added a solution of methyl 3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzoate (0.24 g, 0.65 mmol, step a, example 19) in THF (5 mL). The reaction mixture was stirred at -78 °C for 1 h, quenched with 10% AcOH (10 mL) and H_2O (50 mL) and extracted with ethyl acetate (50 mLx2). The combined organic layers were washed with water and brine, dried over Na_2SO_4, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl 2-[3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)]-2-oxoethylphosphonate as a colorless oil (0.28 g, 63%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.05 (s, 2 H), 6.85 (d, J = 3.3 Hz, 1 H), 6.71 (d, J = 9.0 Hz, 1 H), 6.40 (dd, J = 3.3, 9.0 Hz, 1 H), 4.08 (q, J = 6.3 Hz, 1 H), 3.81 (s, 3 H), 3.60 (d, J = 23.1 Hz, 2 H), 3.35 - 3.25

(m, 1 H), 1.32 (t, $J = 6.9$ Hz, 6 H), 1.19 (d, $J = 6.9$ Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; mobile phase = ethyl acetate-hexanes (2:3); $R_f = 0.2$.

Step b:

To a stirred solution of diethyl 2-[3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)]-2-oxoethylphosphonate (0.26 g, 0.54 mmol) in CH_2Cl_2 (7 mL) at 0 °C was added TMSBr (0.83 g, 0.8 mL, 5.4 mmol). The reaction mixture was stirred at 0 °C for 30 min, allowed to warm to room temperature and stirred for 16 h. The solvent was removed under reduced pressure and the residue was dissolved in CH_3OH (3 mL). The solvent was removed under reduced pressure to afford 2-[3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]-2-oxoethylphosphonic acid as a white solid (0.2 g, 83%): ^{1}H NMR (300 MHz, CD_3OD): δ 8.09 (s, 2 H), 6.83 (d, $J = 3.3$ Hz, 1 H), 6.71 (d, $J = 9.0$ Hz, 1 H), 6.40 (dd, $J = 3.3, 9.0$ Hz, 1 H), 3.81 (s, 3 H), 3.60 (d, $J = 22.1$ Hz, 2 H), 3.35-3.25 (m, 1 H), 1.19 (d, $J = 6.9$ Hz, 6 H).

Step c:

To a stirred solution of 2-[3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]-2-oxoethylphosphonic acid (0.17 g, 0.40 mmol) in CH_2Cl_2 (5 mL) at -78 °C was added BBr_3 (1.0 mL, 1.0 mmol, 1.0 M in CH_2Cl_2). The reaction mixture was stirred at room temperature for 14 h, poured into ice water (25 mL) and stirred for 1 h. The reaction mixture was extracted with ethyl acetate (50 mLx2). The combined organic layers were washed with water and brine, dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was recrystallized from CH_2Cl_2, filtered and dried to afford 2-[3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylphenoxy) phenyl]-2-oxoethylphosphonic acid as a yellow solid (0.14 g, 92%, m.p.: 83-85 °C, 98% pure): ^{1}H NMR (300 MHz, CD_3OD): δ 8.18 (s, 2 H), 6.71 (d, $J = 3.0$ Hz, 1 H), 6.65 (d, $J = 8.7$ Hz, 1 H) 6.37 (dd, $J = 3.0, 8.7$ Hz, 1 H), 3.65 (d, $J = 37.8$ Hz, 2 H) 3.30 - 3.20 (m, 1 H), 1.18 (d, $J = 6.9$ Hz, 6 H); LC-MS $m/z = 420$ $[C_{17}H_{17}Cl_2O_6P + H]^+$; HPLC conditions: ODSAQ AQ-303-5 column; mobile phase = CH_3OH:TFA (7:3) flow rate = 1.0 mL/min; detection = UV @ 254 nm retention time in min: 13.26; Anal Calcd: ($C_{17}H_{17}Cl_2O_6P$) Calcd: C: 48.09; H: 4.18. Found: C, 47.97; H: 4.39.

Example 22

Compound 22: [3,5-dichloro-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenylamino]methylphosphonic acid

Step a:

To a solution of 4-amino-2,6-dichlorophenol (4.0 g, 22.5 mmol) in THF (25 mL) was added *t*-BOC anhydride (5.88 g, 27.0 mmol). The reaction mixture was heated under reflux for 2.5 h and the solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:9) to afford 3,5-dichloro-4-hydroxyphenylcarbamic acid *t*-butyl ester as an off-white solid (5.80 g, 93%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.70 (s, 1 H), 9.44 (s, 1 H), 7.46 (s, 2 H), 1.48 (s, 9 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (3:7); R_f = 0.39.

Step b:

To a mixture of bis(4-methoxy-3-*iso*-propylphenyl)iodonium tetrafluoroborate (2.76 g, 5.39 mmol) and copper powder (0.46 g, 7.18 mmol) in CH_2Cl_2 (20.0 mL) at 0 °C was added a solution of TEA (0.55 mL, 3.95 mmol) and 3,5-dichloro-4-hydroxyphenylcarbamic acid *tert*-butyl ester (1.00 g, 3.59 mmol) in dichloromethane (10.0 mL). The reaction mixture was stirred at room temperature for 14 h and filtered through a Celite plug. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:19) to afford 3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenylcarbamic acid *tert*-butyl ester as an off-white solid (1.45 g, 95%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.81 (s, 1 H), 7.68 (m, 2 H), 6.79 (m, 2 H), 6.42 (m, 1 H), 3.75 (s, 3 H), 3.20 (m, 1 H), 1.51 (s, 9 H), 1.33 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (3:7); R_f = 0.64.

Step c:

To a mixture of 3,5-dichloro-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenylcarbamic acid *tert*-butyl ester (0.400 g, 0.94 mmol) in THF (12.0 mL) at 0 °C was added sodium hydride (0.064 g, 1.22 mmol, 60% dispersion in oil). The reaction mixture was stirred at room temperature for 1 h and cooled to 0 °C. To the stirring mixture was added diethyl trifluoromethanesulfonyloxymethylphosphonate (0.18 g, 0.94 mmol). The reaction mixture was stirred at room temperature for 2 h, quenched with water and diluted with ethyl acetate. The organic layer was washed with

water and brine and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (2:3) to afford diethyl *N-tert*-butoxycarbonyl-[3,5-dichloro-4-(3-*iso*-propyl-4'-methoxyphenoxy)phenylamino]methylphosphonate as an oil (0.34 g, 63%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.64 (s, 2 H), 6.90 (m, 1 H), 6.76 (s, 1 H), 6.45 (m, 1 H), 4.95 (d, J = 9.0 Hz, 2 H); 4.01 (m, 4 H); 3.76 (s, 3 H), 3.21 (m, 1 H), 1.43 (s, 9 H), 1.20 (m, 6 H), 1.13 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:3); R_f = 0.15

Step d:

To a solution of diethyl *N-tert*-butoxycarbonyl-[3,5-dichloro-4-(3-*iso*-propyl-4'-methoxy-phenoxy)phenylamino]methyl)phosphonate (0.25 g, 0.43 mmol) in CH_2Cl_2 (6.0 mL) at 0 °C was added bromotrimethylsilane (0.86 mL, 6.50 mmol). The reaction mixture was stirred at room temperature 16 h and the solvent was removed under reduced pressure. The residue was dissolved in dichloromethane (5.0 mL), cooled to -78 °C and to it was added BBr_3 (2.84 mL, 2.84 mmol, 1.0 M solution in CH_2Cl_2). The reaction mixture was stirred at -78 °C for 10 min, allowed to warm to room temperature and stirred for 16 h. The reaction mixture was poured into ice, diluted with ethyl acetate and washed with water. The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure to afford [3,5-dichloro-4-(4'-hydroxy-3-*iso*-propylphenoxy)phenylamino]methylphosphonic acid as an off-white solid (0.15 g, 85% over two steps): mp: 97-100 °C; LC-MS *m/z* = 405,407 $[C_{16}H_{18}Cl_2NO_5P + H]^+$; ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.02 (s, 2 H), 6.90 (m, 2 H), 6.71 (m, 2 H), 6.32 (m, 2 H), 3.36 (m, 2 H), 3.21 (m, 1 H), 1.17 (d, J = 6.0 Hz, 6 H); Anal. Calcd for ($C_{16}H_{18}Cl_2NO_5P$ + 0.1 $C_4H_8O_2$ + 0.3 H_2O): C, 46.85; H, 4.65; N, 3.33. Found: C, 47.09; H, 4.94; N, 3.50.

Example 23

Compound 23: ***N*-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzamido]methyl phosphonic acid**

Step a:

To a solution of methyl 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzoate (8.53 g, 16.7 mmol, intermediate for the synthesis of Example 19-3) in methanol (60.0 mL) at 0 °C was added a solution of 1 N NaOH (28.15 mL, 28.15 mmol). The reaction mixture was stirred at room temperature for 16 h and

acidified with cold concentrated HCl. The reaction mixture was extracted with ethyl acetate (10.0 mL) and the organic layer was dried over $MgSO_4$. The solvent was removed under reduced pressure to afford 4-(3'-*iso*-propyl-4'-methoxyphenoxy)-3,5-dimethylbenzoic acid as a pink solid (1.38 g, 78%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 12.88 (s, 1 H), 7.76 (s, 2 H), 6.85 (m, 1 H), 6.75 (m, 1 H), 6.34 (m, 1 H), 3.73 (s, 3H), 3.20 (m, 1 H), 2.11 (s, 6 H), 1.12 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (17:3); R_f = 0.00.

Step b:

To a mixture of 4-(3'-*iso*-propyl-4'-methoxyphenoxy)-3,5-dimethylbenzoic acid (0.20 g, 0.63 mmol), diethyl aminomethylphosphonate (0.19 g, 0.76 mmol) and triethylamine in CH_2Cl_2 (10.0 mL) at 0 °C was added EDCI (0.18 g, 0.763 mmol) followed by 1-hydroxy-7-azabenzotriazole (0.09 mg, 0.63 mmol). The reaction mixture was stirred at room temperature for 16 h, concentrated and diluted with ethyl acetate (10.0 mL). The organic layer was washed with water (10 mLx3) and brine, dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by preparatory TLC to afford diethyl *N*-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)- benzamido]methylphosphonate as an oil (0.20 g, 68%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.77 (m, 1 H), 7.69 (s, 2 H), 6.84 (d, J = 9.0 Hz, 1 H), 6.75 (m, 1 H), 6.36 (m, 1 H), 4.05 (m, 4 H), 3.76 (m, 5 H), 3.21 (m, 1 H), 2.11 (s, 6 H), 1.21 (m, 6 H), 1.13 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (1:1); R_f = 0.28.

Step c:

To a solution of diethyl *N*-[4-(3'-*iso*-propyl-4'-methoxyphenoxy)-3,5-dimethylbenzamido]methyl]phosphonate (0.20 g, 0.43 mmol) in CH_2Cl_2 (4.3 mL) at -30 °C was added bromotrimethylsilane (0.56 mL, 4.31 mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was dissolved in dichloromethane (5.0 mL), cooled to -78 °C, and to it was added BBr_3 (1.29 mL, 1.29 mmol, 1.0 M solution in CH_2Cl_2). The reaction mixture was stirred at -78 °C for 3 h, allowed to warm to room temperature and stirred for 16 h. The reaction mixture was poured into ice, extracted with ethyl acetate (10.0 mL) and washed with 2% HCl (20 mLx2) and water (20 mLx2). The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure to afford *N*-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzamido]methylphosphonic acid as an pink solid (0.08 g, 47% over two steps): mp: 163-166 °C; LC-MS m/z = 394

$[C_{19}H_{24}NO_6P + H]^+$; ^{1}H NMR (300 MHz, CD_3OD): δ 7.52 (s, 2 H), 6.51 (m, 2 H), 6.19 (m, 1 H), 3.70 (d, J = 12.0 Hz, 2 H), 3.14 (m, 1 H), 2.04 (s, 6 H), 1.01 (d, J = 6.0 Hz, 6 H); Anal. Calcd for ($C_{19}H_{24}NO_6P$ + 1.0 H_2O): C, 55.47; H, 6.37; N, 3.40. Found: C, 55.30; H, 6.32; N, 3.12.

Example 24

Compound 24: 2-[3,5-dimethoxy-4-(4'-hydroxy-3'-iso propylbenzyl)phenyl]ethylphosphonic acid

Step a:

To a solution of 3,5-dimethoxy-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenol (0.6 g, 1.73 mmol, intermediate for the synthesis of Example 7-2) and DMAP (0.85 g, 6.92 mmol) in CH_2Cl_2 (20 mL) at 0 °C was slowly added trifluoromethanesulfonyl anhydride (0.44 mL, 2.6 mmol). The reaction mixture was stirred at 0 °C for 2 h and quenched by water (10.0 mL). The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:9) to afford 3,5-dimethoxy-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)-1-trifluromethanesulfonyloxyphenyl as a light yellow oil (0.83 g, 100%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.09 (s, 1 H), 6.87 (s, 2 H), 6.80 (s, 2 H), 5.15 (s, 2 H), 3.84 (s, 6 H), 3.81 (s, 2 H), 3.36 (s, 3 H), 3.20 (m, 1 H), 1.14 (d, J = 6.6 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); R_f = 0.73.

Step b:

A mixture of 3,5-dimethoxy-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)-1-trifluromethanesulfonyloxyphenyl (0.83 g, 1.73 mmol), triethylamine (0.96 mL, 6.92 mmol), $Pd(PPh_3)_2Cl_2$ (0.12 g, 0.17 mmol) and diethyl vinylphosphonate (0.37 mL, 2.43 mmol) in DMF (8 mL) was heated at 80 °C for 16 h. The solvent was removed under reduced pressure and the residue was partitioned between EtOAc and saturated aqueous $NaHCO_3$. The organic layer was separated, dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-CH_2Cl_2 (1:1) to afford diethyl 2-[4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)-3,5-dimethoxyphenyl]vinylphosphonate as a light yellow oil (0.1 g, 12%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.50 (d, J = 17.4 Hz, 1 H), 7.29 (s, 1 H), 7.11 (m, 2 H), 6.72 (s, 2 H), 6.22 (t, J = 17.1 Hz, 1 H), 5.17 (s, 2 H), 4.21 (m, 4 H), 3.96 (s, 2 H), 3.87 (s, 6 H), 3.49 (s, 3 H), 3.31 (m, 1 H), 1.40 (t, J = 6.9 Hz, 6 H), 1.23 (d, J =

6.6 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-CH_2Cl_2 (1:3); R_f = 0.4.

Step c:

A mixture of diethyl 2-[3,5-dimethoxy-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenyl]vinylphosphonate (0.1 g, 0.2 mmol) and Pd/C (20 mg, 10%) in MeOH (20 mL) was stirred under one atmosphere of hydrogen at room temperature for 16 h. The mixture was filtered through a Celite plug. The solvent was removed under reduced pressure and the residue (90 mg) was dissolved in CH_2Cl_2 (5 mL). Deprotection with TMSBr as described for the synthesis of Compound 7, step b afforded 2-[3,5-dimethoxy-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenyl]ethylphosphonic acid as light pink foam (73 mg, 91%). ^{1}H NMR (200 MHz, DMSO-d_6): δ 8.88 (s, 1 H), 7.01 (d, J = 1.8 Hz, 1 H), 6.71 (dd, J = 1.8 Hz, J = 8.0 Hz, 1 H), 6.55 (d, J = 8.4 Hz, 1 H), 6.5 (s, 2 H), 3.76 (s, 6 H), 3.69 (s, 2 H), 3.08 (m, 1 H), 2.72 (m, 2 H), 1.82 (m, 2 H), 1.08 (d, J = 7.0 Hz, 6 H), LC-MS m/z = 395 $[C_{20}H_{27}O_6P + H]^+$; Anal Calcd for ($C_{20}H_{27}O_6P$ +1.3 H_2O): C, 57.49; H, 7.14. Found: C, 57.24; H, 7.24.

Using the appropriate starting material, compounds 24-1 to 24-4 were prepared in an analogous manner to that described for the synthesis of compound 24.

Compound 24-1: 2-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenyl]ethylphosphonic acid

Prepared from 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenol (G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607).

mp: 65-68 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 6.93 (s, 2 H), 6.86 (d, J = 1.8 Hz, 1 H), 6.60 (d, J = 8.4 Hz, 1 H), 6.54 (dd, J = 1.8 Hz, J = 8.0 Hz, 1 H), 3.94 (s, 2 H), 3.24 (m, 1 H), 2.82 (m, 2 H), 2.23 (s, 6 H), 2.01 (m, 2 H), 1.15 (d, J = 7.0 Hz, 6 H), LC-MS m/z = 363 $[C_{20}H_{27}O_4P]^+$; Anal Calcd for ($C_{20}H_{27}O_4P$ + 0.6 H_2O + 0.4 CH_3OH): C, 63.47; H, 7.78. Found: C, 63.39; H, 8.06.

Compound 24-2: *trans*-2-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl) phenyl]vinylphosphonic acid

Prepared from 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenol (G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607).

mp: 82-84 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 7.38 (m, 1 H), 7.27 (s, 2 H), 6.84 (d, *J* = 1.8 Hz, 1 H), 6.62 (d, *J* = 8.4 Hz, 1 H), 6.54 (dd, *J* = 1.8 Hz, *J* = 8.0 Hz, 1 H), 6.42 (m, 1 H), 4.00 (s, 2 H), 3.24 (m, 1 H), 2.28 (s, 6 H), 1.15 (d, *J* = 7.0 Hz, 6 H), LC-MS *m/z* = 361 $[C_{20}H_{25}O_4P + H]^+$; Anal Calcd for ($C_{20}H_{25}O_4P$ + 0.3 H_2O): C, 65.67; H, 7.05. Found: C, 65.43; H, 7.13.

<u>**Compound 24-3**: 2-[4-(3'-*sec*-butyl-4'-hydroxy-benzyl)-3,5-dimethyl-phenyl]-ethylphosphonic acid</u>

The title compound was prepared from intermediate intermediate 4-(3'-*sec*-butyl-4'-methoxymethoxy-benzyl)-3,5-dimethyl-phenol, prepared from 4-bromo-2-methyl-phenol according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607, and transformed into the title compound by the procedure used for the synthesis of compound 24 as a light yellow foam; ^{1}H NMR (200 MHz, DMSO-d_6): δ 8.88 (s, 1 H), 6.86 (s, 2 H), 6.80 (s, 1 H), 6.61 (d, *J* = 8.0 Hz, 1 H), 6.46 (d, *J* = 8.0 Hz, 1 H), 3.81 (s, 2 H), 2.88 (m, 1 H), 2.65 (m, 2 H), 2.15 (s, 6 H), 1.75 (m, 2 H), 1.46 (m, 2 H), 1.06 (d, *J* = 7.0 Hz, 3 H), 0.74 (t, *J* = 7.4 Hz, 3 H), LC-MS *m/z* = 377 $[C_{21}H_{29}O4P + H]^+$; Anal Calcd for ($C_{21}H_{29}O_4P$ +1.6 H_2O): C, 62.24; H, 8.01. Found: C, 61.87; H, 7.82.

<u>**Compound 24-4**: 2-[3,5-dimethyl-4-(3'-Ethyl-4'-hydroxy-benzyl)phenyl]ethylphosphonic acid</u>

Intermediate 4-(3'-ethyl-4'-methoxybenzyl)-3,5-dimethylphenol, prepared according to the procedure described in G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607, was transformed into the title compound by the procedure used for the synthesis of compound 24 as a foam (94 mg, 19%); LC- MS *m/z* = 347 $[C_{18}H_{23}O_5P - H]$; ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.98(s, 1H), 6.86(d, 1H, *J* = 3 Hz), 6.72(d, 1H, *J* = 1.8 Hz), 6.60(s, 2H), 6.49(dd, 1H, *J* = 2.8 Hz, *J* = 8.4 Hz), 3.82(s, 2H), 2.71(m, 2H), 2.26(s, 3H), 2.09(s, 3H), 1.66(m, 2H), 1.06(t, 3H, *J* = 9 Hz); Uniplate silica gel, 250 microns; Mobile phase = isopropyl alcohol/ammonium hydroxide/water [7:2:1]; Rf = 0.22; Anal. Calcd for ($C_{19}H_{25}O_4P$ +1.1 H_2O): C, 61.98; H, 7.45; Found: C, 61.88, H, 7.19.

Example 25

Compound 25: [3,5-dimethyl-4-(3'-*iso*-propyl-4'-hydroxybenzoyl)phenoxy]methylphosphonic acid

Step a:

To a stirring solution of (2, 6-dimethyl-4-triisopropylsilanyloxyphenyl)-(3'-*iso*-propyl-4'-methoxymethoxyphenyl)methanol (0.620 g, 1.27 mmol), (G. Chiellini *et al.* *Bioorg. Med. Chem. Lett.* **2000**, *10*, 2607) in THF (10.0 mL) at 0 °C was added tetrabutylammonium fluoride (1.91 mL, 1.91 mmol, 1.0 M solution in THF). The reaction mixture was stirred at room temperature for 20 min, diluted with diethyl ether and washed with water (20 mLx2) and brine. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:4) to afford 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzylhydroxy)phenol as an oil (0.370 g, 88%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.07 (s, 1 H), 7.20 (m, 1 H), 6.90 (m, 1 H), 6.78 (m, 1 H), 6.39 (s, 2 H), 5.98 (d, J = 3.0 Hz, 1 H), 5.52 (d, J = 3.0 Hz, 1 H) 5.18 (s, 2H), 3.38 (s, 3 H), 3.25 (m, 1 H), 2.12 (s, 6 H), 1.16 (m, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (4:1); R_f = 0.15.

Step b:

To a mixture of 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzylhydroxy)phenol (0.380 g, 1.15 mmol) in DMF (10.0 mL) at 0 °C was added Cs_2CO_3 (1.87 g, 5.75 mmol). After 5 min, diethyl trifluoromethanesulfonyloxymethyl phosphonate (0.24 g, 1.15 mmol) was added. The reaction mixture was stirred at 0 °C for 5 h, allowed to warm to room temperature and stirred for 16 h. The reaction mixture was quenched with 1 N HCl, diluted with ethyl acetate, and washed with water (10 mLx4) and brine. The organic layer was concentrated under reduced pressure and the crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:4) as mobile phase to afford diethyl [3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzylhydroxy)phenoxy]methylphosphonate as an oil (0.41 g, 74%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.20 (m, 1 H), 6.92 (m, 1 H), 6.78 (m, 1 H), 6.67 (s, 2 H), 6.03 (d, J = 3.0 Hz, 1 H), 5.64 (d, J = 3.0 Hz, 1 H), 5.18 (s, 2H), 4.38 (d, J = 9.0 Hz, 2 H), 4.11 (m, 4 H), 3.38 (s, 3 H), 3.25 (m, 1 H), 2.19 (s, 6 H), 1.24 (m, 6 H), 1.16 (m, 6

H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (6:4); R_f = 0.35.

Step c:

To a stirred solution of diethyl [3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzylhydroxy)phenoxy]methylphosphonate (0.32 g, 0.66 mmol) in dichloromethane (8.0 mL) at 0 °C was added Dess-Martin periodinane (2.08 mL, 0.99 mmol, 0.48 M solution in CH_2Cl_2). The reaction mixture was stirred room temperature for 16 h, concentrated, diluted with diethyl ether (10.0 mL). To the solution was added a solution of 580 mg of $Na_2S_2O_3$ pentahydrate in 60 mL saturated $NaHCO_3$). After 15 min, the reaction mixture was diluted with ethyl acetate and water and washed with saturated $NaHCO_3$ and brine. The organic layer was concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl [3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzoyl)phenoxy]methylphosphonate as an oil (0.285 g, 89%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.22 (m, 1 H), 7.43 (m, 1 H), 7.13 (m, 1 H), 6.85 (s, 2 H), 5.35 (s, 2H), 4.49 (d, J = 7.5 Hz, 2 H), 4.16 (m, 4 H), 3.43 (s, 3 H), 3.27 (m, 1 H), 2.02 (s, 6 H), 1.29 (m, 6 H), 1.20 (m, 6 H);; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = dichloromethane-methanol (3:97); R_f = 0.52.

Step d:

To a solution of diethyl [3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzoyl)phenoxy]methylphosphonate (0.075 g, 0.16 mmol) in CH_2Cl_2 (3.0 mL) at -30 °C was added bromotrimethylsilane (0.31 mL, 2.4 mmol). The reaction mixture was stirred at room temperature 16 h and the solvent was removed under reduced pressure. The residue was treated with acetonitrile-water (4:1, 5.0 mL) and sonicated. The solvents were removed under reduced pressure. The residue was dissolved in 1 N NaOH and extracted with dichloromethane and ethyl acetate. The aqueous layer was acidified with 2 N HCl and extracted with ethyl acetate. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure to afford [3,5-dimethyl-4-(4'-hydroxy-3-*iso*-propylbenzoyl)phenoxy]methylphosphonic acid as an pink solid (0.05 g, 84%): mp 138 °C; LC-MS m/z = 379 $[C_{19}H_{23}O_6P + H]^+$; ^{1}H NMR (300 MHz, DMSO-d_6): δ 10.50 (s, 1 H), 7.64 (s, 1 H), 7.27 (m, 1 H), 6.87 (m, 1 H), 6.78 (m, 1 H), 4.18 (m, 2 H), 3.18 (m, 1 H), 2.00 (s, 6 H), 3.11 (m, 1 H), 1.17 (d, J = 6.0 Hz, 6 H); HPLC conditions: Column = 3 Chromolith SpeedRODs RP-18e, 100×4.6 mm;

Mobile phase = Solvent A (Acetonitrile) = HPLC grade acetonitrile; Solvent B (buffer) = 20 mM ammonium phosphate buffer (pH 6.1, 0.018 M $NH_4H_2PO_4$/0.002 M $(NH_4)_2HPO_4$) with 5% acetonitrile. Flow rate = 4 mL/min; UV@ 255 nm. Retention time in minutes. (rt = 5.30, 95% purity).

Example 26

Compound 26: 2-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-hydroxybenzyl)phenoxy]ethylphosphonic acid

Step a:

To a stirring solution of 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxymethylbenzyl)phenol (1.00 g, 3.18 mmol, G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607) in DMF (30.0 mL) was added Cs_2CO_3 (5.18 g, 15.90 mmol) followed by 1,2-dibromoethane (1.64 g, 19.08 mmol). The reaction mixture was stirred at 60 °C for 2 d, diluted with ethyl acetate and washed with water (20 mLx4) and brine. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:19) to afford 1-(2-bromoethoxy)-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)-3,5-dimethylbenzene as an oil (0.26 g, 16%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.94 (m, 2 H), 6.67 (m, 3 H), 5.18 (s, 2 H), 4.32 (m, 2 H), 3.95 (s, 2 H), 3.68 (m, 2 H), 3.51 (s, 3 H), 3.37 (s, 3 H), 3.32 (m, 1 H), 2.26 (s, 6 H), 1.22 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (4:1); R_f = 0.91.

Step b:

A mixture of 1-(2-bromoethoxy)-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)-3,5-dimethylbenzene (0.15 g, 0.36 mmol) and triethylphosphite (0.18 g, 1.07 mmol) in DMF (2.0 mL) was heated under reflux for 4 h. The reaction mixture was cooled to rt, diluted with ethyl acetate and extracted with water (10 mLx4) and brine. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:1) to afford diethyl 2-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenoxy]ethylphosphonate as an oil (0.085 g, 50%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.96 (m, 1 H), 6.89 (m, 1 H), 6.62 (m, 3 H), 5.16 (s, 2 H), 4.12 (m, 2 H), 4.07 (m, 4 H) 3.86 (s, 2 H), 3.37 (s, 3 H), 3.22 (m, 1 H), 2.30 (m, 2 H), 2.17 (s,

6 H), 1.25 (m, 6 H), 1.12 (d, $J = 6.0$ Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (3:7); $R_f = 0.10$.

Step c:

Deprotection of diethyl 2-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenoxy]ethylphosphonate with bromotrimethylsilane afforded 2-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]ethylphosphonic acid as a brown oil (0.055 g, 87%): mp: 58-61 °C; LC-MS $m/z = 379$, $[C_{20}H_{27}O_5P + H]^+$; ^{1}H NMR (300 MHz, CD_3OD): δ 6.84 (s, 1 H), 6.66 (s, 2 H), 6.56 (m, 2 H), 4.26 (m, 2 H), 3.90 (s, 2 H), 3.22 (m, 1 H), 2.30 (m, 1 H), 2.22 (s, 6 H), 1.15 (d, $J = 6.0$ Hz, 6 H); Anal. Calcd for ($C_{20}H_{27}O_5P + 0.6\ H_2O$): C, 61.72; H, 7.30. Found: C, 61.96, H, 7.73.

Example 27

Compound 27: [3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid

Step a:

To a solution of 2-bromopropene (6.0 g, 49.60 mmol) in diethyl ether (200 mL) at -78 °C was added *t*-butyllithium (36.0 mL). The reaction mixture was stirred at –78 °C for 3 h and to it was added tributyltin chloride (16.1 g, 49.60 mmol). The reaction mixture was allowed to warm up to room temperature and stirred for 16 h. The reaction mixture was filtered through a plug of Celite and the filtrate was washed with saturated NH_4Cl. The organic layer was dried over $MgSO_4$, filtered and concentrated to afford the crude product as colorless oil that was used for next step without further purification.

Step b:

To a solution of 3-bromo-4-fluorobenzaldehyde (1.23 g, 6.04mmol) in dioxane (20 mL) was added the product obtained from *step a* followed by $Pd(Ph_3)_2Cl_2$. The reaction mixture was heated at 110 °C for 16 h, cooled to room temperature and filtered through a plug of Celite. The solvent was removed under reduced pressure and the crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:19) to afford 4-fluoro-3-isopropenylbenzaldehyde (500 mg, 50%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.89 (m, 1 H), 7.82 (m, 1 H), 7.24(m, 1 H), 5.36 (s, 2 H), 2.21 (s, 3 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:19); $R_f = 0.60$.

Step c:

To a solution of 4-bromo-3,5-dimethyl-triisopropylsilanoxybenzene (1.29 g, 3.6 mmol, G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000**, *10*, 2607) in THF at -78 °C was added *n*-butyllithium (1.58 mL, 3.96 mmol, 2.5 M in THF). After 30 min, a solution of 4-fluoro-3-isopropenylbenzaldehyde (500 mg, 3.0 mmol) in THF was added. The reaction mixture was stirred at –78 °C for 1 h, allowed to warm to room temperature, diluted with EtOAc and quenched with water. The organic layer was dried over $MgSO_4$, filtered and concentrated to afford crude 1-(2,6-dimethyl-4-triisopropylsilanyloxyphenyl)-1-(4'-fluoro-3'-isopropenylphenyl)methanol as an oil: ^1H NMR (200 MHz, $CDCl_3$): δ 7.18 (m, 1 H), 7.02 (m, 1 H), 6.94 (m, 1 H), 6.56 (s, 2 H), 6.22 (s, 1 H), 5.18 (m, 2 H), 2.20 (s, 6 H), 2.08 (s, 3 H), 1.25 (m, 3 H), 1.11 (m, 18).

Step d:

A solution of 1-(2,6-dimethyl-4-triisopropylsilanyloxyphenyl)-1-(4'-fluoro-3'-isopropenylphenyl)methanol (1.2 g, 2.71 mmol) and Pd/C (0.1 g, 10%) in EtOH/HOAc (9:1, 10 mL) was stirred under a H_2 atmosphere for 16 h. The reaction mixture was filtrated through a plug of Celite and concentrated to afford the crude 3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propylbenzyl)triisopropylsilanoxybenzene that was used for the next step without further purification.

Step e:

To a solution of 3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propylbenzyl)triisopropylsilanoxybenzene in THF (10 mL) at 0 °C was added TBAF (1 M, 4.0 mL). The reaction mixture was stirred for 3 h, diluted with ethyl acetate 920 mL) and quenched with water (10 mL). The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:9) to afford 3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propylbenzyl)phenol (450 mg, 61% for two steps): ^1H NMR (300 MHz, $CDCl_3$): δ 6.97 (d, J = 7.4 Hz, 1 H), 6.86 (m, 1 H), 6.69 (m, 1 H), 6.60 (s, 2 H), 3.95 (s, 2 H), 3.20 (m, 1 H), 2.22 (s, 6 H), 1.25 (d, J = 6.4 Hz, 6 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); R_f = 0.50.

Step f:

[3,5-Dimethyl-4-(4'-fluoro-3'-*iso*-propylbenzyl)phenoxy]methylphosphonic acid was prepared from 3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propylbenzyl)phenol following the same procedure as described in compound 7, step b: ^1H NMR (300 MHz, DMSO-d_6): δ

7.03 (m, 1 H), 6.93 (m, 1 H), 6.71 (s, 2 H), 6.64 (m, 1 H), 4.03 (d, J = 10.2 Hz, 2 H), 3.89 (s, 2 H), 3.09 (m, 1 H), 2.15 (s, 6 H), 1.16 (d, J = 6.6 Hz, 6 H). mp: > 200 °C; LC-MS m/z = 367 $[C_{19}H_{24}FO_4P + H]^+$; Anal. Calcd for ($C_{19}H_{24}FO_4P + 0.4\ H_2O$): C, 61.09; H, 6.69. Found: C, 60.85; H, 6.32.

Using the appropriate starting material, compound 27-1 was prepared in an analogous manner to that described for the synthesis of compound 27.

Compound 27-1: [3,5-dichloro-4-(4'-fluoro-3'-*iso*-propyl-benzyl)-phenoxy]methylphosphonic acid

Intermediate (2,6-dichloro-4-triisopropylsilanyloxy-phenyl)-(4-fluoro-3-*iso*-propyl-phenyl)-methanol was prepared by the procedure described for the synthesis of compound 27, steps a, b, c, d as an oil (520 mg, 98%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.24 (m, 1H), 6.98 (m, 2H), 6.91 (s, 2H), 6.52 (s, 1H), 4.48 (s, 1H), 3.24 (m, 1H), 1.25 (m, 3H), 1.15 (s, 24H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:19); R_f = 0.86.

Step d:

To a solution of (2,6-dimethyl-4-triisopropylsilanyloxy-phenyl)-(4-fluoro-3-*iso*-propyl-phenyl)-methanol (520 mg, 1.08 mmol) in CH_2Cl_2 (10 mL)was added TFA (1.53 M, 0.7 mL) followed by triethylsilane (0.6 mL, 3.77 mmol) at r.t. After stirring for 2h, the reaction mixture was diluted with EtOAc and water and the layers were separated. The aqueous layer was further extracted with EtOAc. The combined organic layers were washed with Sat. $NaHCO_3$, water and brine, dried over $MgSO_4$, filtered and concentrated. The residue was purified by column chromatography (silica gel, hexanes) to provide 3,5-dichloro-4-(4'-fluoro-3'-*iso*-propyl-benzyl)-phenoxy]-triisopropylsilane as a colorless liquid (360 mg, 72%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.11 (m, 1H), 6.91 (m, 4H), 4.21 (s, 2H), 3.19 (m, 1H), 1.24 (m, 3H), 1.17 (m, 24H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes; R_f = 0.68.

Intermediate 3,5-dichloro-4-(4'-fluoro-3'-*iso*-propyl-benzyl)-phenoxy]-triisopropylsilane was transformed into the title compound by the procedure described for the synthesis of compound 35, steps e, f and h to give a white solid (55 mg, 35%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.22 (s, 2H), 7.18 (m, 1H), 7.04 (m, 1H), 6.87 (m, 1H), 4.22 (d, J = 9.6 Hz, 2H), 6.60 (s, 2H), 3.12 (m, 1H), 1.19 (d, J = 6.9 Hz, 6H). mp =

132~135, LC-MS $m/z = 408$ $[C_{17}H_{18}Cl_2FO_4P + H]^+$; Anal. Calcd for ($C_{17}H_{18}Cl_2FO_4P$ + 0.2 H_2O): C, 49.70; H, 4.51. Found: C, 49.58; H, 4.24.

Example 28

Compound 28: *trans*-2-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenyl]vinylphosphonic acid

Step a:

To a mixture of bis(4-methoxy-3-*iso*-propylphenyl)iodonium tetrafluoroborate (4.80 g, 9.38 mmol) and copper powder (0.79 g, 12.52 mmol) in CH_2Cl_2 (15.0 mL) at 0 °C was added a solution of triethylamine (0.96 mL, 6.89 mmol) and 3,5-dimethyl-4-hydroxybenzaldehyde (0.94 g, 6.26 mmol) in dichloromethane (15.0 mL). The reaction mixture was stirred at room temperature for 3 d and filtered through a Celite plug. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:19) to afford 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzaldehyde as an oil (2.00 g, 100%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.96 (s, 1 H), 7.75 (s, 2 H), 6.85 (m, 1 H), 6.73 (m, 1 H), 6.36 (m, 1 H), 3.74 (s, 3 H), 3.19 (m, 1 H), 2.15 (s, 6 H), 1.12 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (17:3); R_f = 0.51.

Step b:

To a mixture of tetraethyl methylenediphosphonate (0.20 mL, 0.80 mmol) and THF (7.0 mL) at 0 °C was added sodium hydride (0.033 g, 0.804 mmol, 60% dispersion in oil). The reaction mixture was stirred at room temperature for 30 min and to it was added 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzaldehyde (0.20 g, 0.67 mmol). The reaction mixture was stirred at room temperature for 1 h, quenched with cold aqueous solution of NH_4Cl, diluted with ethyl acetate and washed with water and brine. The solvent was removed under reduced pressure and the residue was purified by preparatory TLC on silica gel, eluting with acetone-hexanes (1:4) to afford diethyl *trans*-2-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]vinylphosphonate as an oil (0.21 g, 74%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.53 (s, 2 H), 7.32 (m, 2 H), 6.84 (m, 1 H), 6.74 (m, 1 H), 6.59 (m, 2 H), 6.36 (m, 1 H), 4.00 (m, 4 H), 3.73 (s, 3 H), 3.20 (m, 1 H), 2.07 (s, 6 H), 1.27 (m, 6 H), 1.10 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (4:1); R_f = 0.13.

Step c:

To a solution of diethyl *trans*-2-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]vinylphosphonate (0.22 g, 0.50 mmol) in CH_2Cl_2 (5.0 mL) at -30 °C was added bromotrimethylsilane (0.66 mL, 5.00 mmol). The reaction mixture was stirred at room temperature 16 h and the solvent was removed under reduced pressure. The residue was dissolved in dichloromethane (5.0 mL) and cooled to -78 °C. To it was added BBr_3 (1.49 mL, 1.49 mmol, 1.0 M solution in CH_2Cl_2). The reaction mixture was stirred at -78 °C for 3 h, allowed to warm to room temperature and stirred for 16 h. The reaction mixture was poured into ice, concentrated, and extracted with ethyl acetate. The organic solution was washed with 2% HCl (20 mL) and water (20 mLx3), dried over $MgSO_4$ and filtered. The solvent was removed under reduced pressure to afford *trans*-2-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenyl]vinylphosphonic acid as an off-white solid (0.08 g, 44% over two steps): mp 92-94 °C; LC-MS *m/z* = 363 $[C_{19}H_{23}O_5P + H]^+$; ^{1}H NMR (300 MHz, CD_3OD): δ 7.35 (s, 2 H), 7.10 (s, 1 H), 6.65 (s, 2 H), 6.32 (m, 2 H), 3.21 (m, 1 H), 2.12 (s, 6 H), 1.15 (d, *J* = 6.0 Hz, 6 H); HPLC conditions: Column = 3 Chromolith SpeedRODs RP-18e, 100×4.6 mm; Mobile phase = Solvent A (Acetonitrile) = HPLC grade acetonitrile; Solvent B (buffer) = 20 mM ammonium phosphate buffer (pH 6.1, 0.018 M $NH_4H_2PO_4$/0.002 M $(NH_4)_2HPO_4$) with 5% acetonitrile. Flow rate = 4 mL/min; UV@ 255 nm. Retention time in minutes. (rt = 5.71, 98% purity).

Example 29

Compound 29: 3-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenyl]propylphosphonic acid

Step a:

To a mixture of triethyl phosphonoacetate (0.16 mL, 0.80 mmol) in THF (7.0 mL) at 0 °C was added NaH (0.033 g, 0.804 mmol, 60% dispersion in oil). The reaction mixture was stirred room temperature for 30 min and to it was added 3,5-dimethyl-4-(3-*iso*-propyl-4-methoxyphenoxy)benzaldehyde (0.20 g, 0.67 mmol, Example 28, step a). The reaction mixture was stirred at room temperature for 1 h, quenched with cold saturated NH_4Cl, diluted with ethyl acetate and washed with water and brine. The solvent was removed under reduced pressure and the residue was purified by preparatory TLC on silica gel, eluting with acetone-hexanes (3:17) to afford ethyl *trans*-3-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]acrylate as an oil (0.24 g, 97%):

^{1}H NMR (300 MHz, DMSO-d_6): δ 7.60 (m, 3 H), 6.83 (m, 1 H), 6.76 (m, 1 H), 6.60 (m, 1 H), 6.36 (m, 1 H), 4.21 (m, 4 H), 3.73 (s, 3H), 3.21 (m, 1 H), 2.08 (s, 6 H), 1.27 (m, 6 H), 1.12 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (4:1); R_f = 0.62.

Step b:

To a mixture of ethyl *trans*-3-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]acrylate (1.10 g, 3.35 mmol) in THF (20.0 mL) at 0 °C was added DIBAL-H (4.68 mL, 4.68 mmol, 1.0 M solution in THF). The reaction mixture was stirred at room temperature for 2 h, quenched with cold 1 N HCl, diluted with ethyl acetate and washed with water and brine. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:9) to afford *trans*-3-[3,5-dimethyl 4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]-prop-2-en-1-ol as an oil (0.50 g, 81%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.22 (s, 2 H), 6.97 (m, 0.5 H), 6.84 (m, 1.5 H), 6.73 (m, 1 H), 6.36 (m, 2 H), 4.87 (m, 1 H), 4.14 (m, 2 H), 3.73 (s, 3 H), 3.21 (m, 1 H), 2.05 (s, 6 H), 1.11 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (17:3); R_f = 0.11.

Step c:

To a mixture of *trans*-3-[3,5-dimethyl 4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]-prop-2-en-1-ol (0.50 g, 1.53 mmol) in methanol (15.0 mL) was added 10% Pd/C (0.10 g, 20% wt/wt). The reaction mixture was stirred under H_2 (balloon) at room temperature for 6 h and filtered through a plug of Celite. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (3:7) to afford 3-[3,5-dimethyl 4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]propanol as an oil (0.36 g, 72%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.97 (s, 2 H), 6.82 (m, 1 H), 6.74 (m, 1 H), 6.30 (m, 1 H), 4.49 (m, 1 H), 3.73 (s, 3 H), 3.43 (m, 2 H), 3.21 (m, 1 H), 2.57 (m, 2 H), 2.03 (s, 6 H), 1.73 (m, 2 H), 1.11 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (17:3); R_f = 0.26.

Step d:

To a stirred solution of triphenylphosphine (0.36 g, 1.39 mmol) and CBr_4 (0.46 g, 1.39 mmol) in diethyl ether (12.0 mL) at room temperature was added 3-[3,5-dimethyl 4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]propanol (0.35 g, 1.06 mmol). The reaction mixture was stirred for 16 h, filtered and concentrated under reduced pressure. The

crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:9) to afford 1-bromo-3-[3,5-dimethyl 4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]propane as an oil (0.30 g, 72%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.00 (s, 2 H), 6.83 (m, 1 H), 6.80 (m, 1H), 6.31 (m, 1 H), 3.73 (s, 3 H), 3.53 (m, 2 H), 3.20 (m, 1 H), 2.70 (m, 2 H), 2.12 (m, 2 H), 2.03 (s, 6 H), 1.11 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (4:1); R_f = 0.75.

Step e:

A mixture of 1-bromo-3-[3,5-dimethyl 4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]propane (0.30 g, 0.77 mmol) and triethylphosphite (0.39 g, 2.31 mmol) in DMF (7.0 mL) was heated under reflux for 2.5 h and cooled to room temperature. The mixture was diluted with ethyl acetate and washed with water and brine. The organic layer was concentrated under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:3) to afford diethyl 3-[3,5-dimethyl 4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]propylphosphonate as an oil (0.11 g, 32%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.97 (s, 2 H), 6.83 (d, J = 9.0 Hz, 1 H), 6.72 (d, J = 3.0 Hz, 1 H), 6.32 (m, 1 H), 3.99 (m, 4 H), 3.73 (s, 3 H), 3.35 (m, 2 H), 3.17 (m, 1 H), 2.62 (m, 2 H), 2.02 (s, 6 H), 1.75 (m, 4 H), 1.23 (m, 6 H), 1.10 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (1:4); R_f = 0.17.

Step f:

To a solution of diethyl 3-[3,5-dimethyl 4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]propylphosphonate (0.10 g, 0.22 mmol) in CH_2Cl_2 (5.0 mL) at -30 °C was added bromotrimethylsilane (0.30 mL, 2.23 mmol). The reaction mixture was stirred at room temperature 16 h and the solvent was removed under reduced pressure. The residue was dissolved in dichloromethane (3.0 mL) and cooled to –78 °C. To it was added BBr_3 (0.66 mL, 0.66 mmol, 1.0 M solution in CH_2Cl_2). The reaction mixture was stirred at -78 °C for 3 h, allowed to warm to room temperature and stirred for 16 h. The reaction mixture was poured into ice, concentrated and extracted with ethyl acetate (10 mL). The organic solution was washed with 0.5 M HCl (20 mLx2) and water (20 mLx2), dried over MgSO4, filtered and concentrated under reduced pressure to afford 3-[3,5-dimethyl 4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenyl]propylphosphonic acid as a white solid (0.50 g, 60% over two steps): mp: 60-63 °C; LC-MS m/z = 379

$[C_{20}H_{27}O_5P + H]^+$; ^{1}H NMR (200 MHz, DMSO-d_6): δ 8.80 (s, 1 H), 6.85 (s, 2 H), 6.56 (m, 2 H), 6.10 (m, 1 H), 3.05 (m, 1 H), 2.40 (m, 2 H), 1.90 (s, 6 H), 1.49 (m, 2 H), 1.33 (s, 2 H), 1.03 (d, J = 6.0 Hz, 6 H); Anal. Calcd for ($C_{20}H_{27}O_5P$ + 1.1 H_2O): C, 60.32; H, 7.39. Found: C, 60.19 H, 7.32.

Example 30

Compound 30: 2-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]ethylphosphonic acid

Step a:

A solution of diethyl *trans*-2-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]vinylphosphonate (1.77g, 4.10 mmol, Example 28, step b) and Pd/C (177mg) in EtOH/HOAc (10 mL, 9:1)) was stirred under a H_2 atmosphere for 5 h. The reaction mixture was filtrated through a plug of Celite and the solvent was removed under reduced pressure. The residue was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl 2-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]ethylphosphonate (1.29 g, 74%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.94 (s, 2 H), 6.81 (d, J = 3.0 Hz, 1 H), 6.68 (d, J = 8.7 Hz, 1 H), 6.36 (m, 1 H), 4.15 (m, 4 H), 3.30 (m, 1 H), 2.88 (m, 2 H), 2.13 (s, 6 H), 2.05 (m, 2 H), 1.37 (m, 6 H), 1.21 (d, J = 6.9 Hz, 6 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); R_f = 0.35.

Step b:

Deprotection of diethyl 2-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]ethylphosphonate with bromotrimethylsilane afforded 2-[3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenyl]ethylphosphonic acid: ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.98 (s, 2 H), 6.78 (d, J = 9.3 Hz, 1 H), 6.72 (d, J = 2.7 Hz, 1 H), 6.26 (m, 1 H), 3.70 (s, 3 H), 3.16 (m, 1 H), 2.71 (m, 2 H), 2.00 (s, 6 H), 1.81 (m, 2 H), 1.10 (d, J = 6.6 Hz, 6 H). LC-MS m/z = 379 $[C_{20}H_{27}O_5P + H]^+$; Anal. Calcd for ($C_{20}H_{27}O_5P$ + 0.7 H_2O): C, 61.43; H, 7.32. Found: C, 61.59; H, 7.60.

Example 31

Compound 31: [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenoxy]methylphosphonic acid

To a solution of 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzaldehyde (0.18 g, 0.60 mmol, Example 28, step a) in dichloromethane (6.0 mL) at 0 °C was added

m-chloroperoxybenzoic acid (0.22 g, 0.905 mmol). The reaction mixture was stirred at room temperature for 16 h. The solvent was removed under reduced pressure and the residue was diluted with ethyl acetate. The organic solution was washed with saturated sodium bicarbonate (2x10mL) and water. The solvent was removed under reduced pressure and the residue was dissolved in methanol (5 mL). To the solution was added 1 N NaOH (1.81 mL, 1.81 mmol) and the reaction mixture was stirred at room temperature for 4 h. The reaction mixture was diluted with ethyl acetate, acidified with 2 N HCl and washed with brine. The solvent was evaporated and the residue was purified by preparatory TLC eluting with acetone-hexanes (1:4) to afford 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenol as an oil (0.08 g, 47%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.17 (s, 1 H), 6.82 (m, 1 H), 6.70 (m, 1 H), 6.51 (s, 2 H), 6.32 (m, 1 H), 3.71 (s, 3 H), 3.18 (m, 1 H), 1.95 (s, 6 H), 1.12 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (4:1); R_f = 0.44.

Intermediate 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenol was converted to [3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenoxy]methylphosphonic acid following the procedure described for the synthesis of compound 8: mp 60-64 °C; LC-MS m/z = 367 $[C_{18}H_{23}O_6P + H]^+$; ^{1}H NMR (200 MHz, DMSO-d_6): δ 8.88 (s, 1 H), 6.76 (s, 2 H), 6.60 (m, 2 H), 6.17 (m, 1 H), 4.04 (d, J = 15.0 Hz, 2 H), 3.13 (m, 1 H), 2.01 (s, 6 H), 1.10 (d, J = 6.0 Hz, 6 H); Anal. Calcd for ($C_{18}H_{23}O_6P + 0.7\ H_2O$): C, 57.05; H, 6.49. Found: C, 57.10 H, 6.63.

Example 32:

Compound 32: 3-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)]phenyl-2-oxopropylphosphonic acid

Step a:

To a stirred solution of 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy) benzaldehyde (4.1 g, 15.2 mmol, Example 28, step a) in methanol (35 mL) at 0 °C was slowly added $NaBH_4$ (1.16 g,, 30.5 mmol). The reaction mixture was stirred at room temperature for 5 h and the solvent was removed under reduced pressure. The residue was dissolved in ethyl acetate (150 mL), washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (2:4) to afford 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzyl alcohol as a white solid (3.4 g, 83%, m.p.: 78-80 °C): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.12 (s, 2 H), 6.80 (d, J = 3.3 Hz,

2 H), 6.67 (d, $J = 9.0$ Hz, 1 H), 6.36 (dd, $J = 3.0$, 8.7 Hz, 1 H), 4.68 (s, 2 H), 3.80 (s, 3 H), 3.35 - 3.25 (m, 1 H), 2..16 (s, 6 H), 1.19 (d, $J = 7.2$ Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; mobile phase = ethyl acetate-hexanes (2:4); $R_f = 0.5$.

Step b:

To a stirred solution of 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzyl alcohol (1.0 g, 3.4 mmol) in DME (10 mL) at 0 °C was added phosphorous tribromide (1.8 g, 0.5 mL, 6.8 mmol). The reaction mixture was stirred at 0 °C for 5 h, quenched with methanol (2 mL) and stirred for 30 min. The reaction mixture was poured into ice water and extracted with ether (100 mL). The organic layer was washed with brine, dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford crude 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzyl bromide as an oil (1.02 g, 82%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.15 (s, 2 H), 6.81 (d, $J = 3.0$ Hz, 1 H), 6.67 (d, $J = 9.0$ Hz, 1 H), 6.34 (dd, $J = 3.0$, 8.7 Hz, 1 H), 4.51 (s, 2 H), 3.80 (s, 3 H), 3.40 - 3.25 (m, 1 H), 2..15 (s, 6 H), 1.20 (d, $J = 7.2$ Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; mobile phase = ethyl acetate-hexanes (2:4); $R_f = 0.7$.

Step c:

To a stirred solution of sodium cyanide (0.23 g, 4.69 mmol) in H_2O (2 mL) at room temperature was added a solution of 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)benzyl bromide (0.85 g, 2.34 mmol) in ethanol (5 mL). The reaction mixture was heated at 80 °C for 2 h, cooled to room temperature, and poured into ice water (100 mL). The mixture was stirred for 1 h and extracted with ethyl acetate (2x100 mL). The combined organic layers were washed with water and brine, dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:4) to afford 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenylacetonitrile as a brown solid (0.64 g, 85%, m.p.: 56 -58 °C): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.07 (s, 2 H), 6.78 (d, $J = 3.3$ Hz, 1 H), 6.68 (d, $J = 9.0$ Hz, 1 H), 6.35 (dd, $J = 3.0$, 8.7 Hz, 1 H), 3.80 (s, 3 H), 3.73 (s, 2 H), 3.40 - 3.25 (m, 1 H), 2.16 (s, 6 H), 1.19 (d, $J = 7.2$ Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; mobile phase = ethyl acetate-hexanes (1:4); $R_f = 0.5$.

Step d:

To a stirred solution of 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenylacetonitrile (0.75 g, 2.42 mmol) in acetic acid (7 mL) was added

a 50% solution of H_2SO_4 (14 mL). The reaction mixture was heated at 105 °C, for 3 h, cooled to room temperature and poured into ice water (100 mL). The mixture was stirred for 1 h and extracted with ethyl acetate (3x50 mL). The combined organic layers were washed with water and brine, dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenylacetic acid as a brownish solid (0.62 g, 85%, m.p.: 118-120 °C): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.11 (s, 2 H), 6.82 (d, J = 2.7 Hz, 1 H), 6.80 (d, J = 8.7 Hz, 1 H), 6.37 (dd, J = 3.3, 8.7 Hz, 1 H), 3.80 (s, 3 H), 3.61 (s, 2 H), 3.38-3.25 (m, 1 H), 2.11 (s, 6 H), 1.17 (d, J = 7.2 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; mobile phase = ethyl acetate-hexanes (1:1); R_f = 0.2.

Step e:

To a stirred cold solution of methanol (15 mL) and acetyl chloride (3 mL, 86.0 mmol) at 0 °C was added dropwise a solution of 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenylacetic acid (0.7 g, 4.3 mmol) in methanol (5 mL). The reaction mixture was heated under reflux for 5 h and cooled to room temperature. The solvent was removed under reduced pressure and the residue was dissolved in ethyl acetate (100 mL). The organic solution was washed with water and brine, dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was triturated with hexane, filtered and dried under reduced pressure to afford methyl 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenylacetate as a yellow solid (0.69 g, 95%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.02 (s, 2 H), 6.82 (d, J = 2.7 Hz, 1 H), 6.66 (d, J = 8.7 Hz, 1 H), 6.38 (dd, J = 3.3, 8.7 Hz, 1 H), 3.79 (s, 3 H), 3.75 (s, 3 H), 3.60 (s, 2 H), 3.28 - 3.25 (m, 1 H), 2.14 (s, 6 H), 1.20 (d, J = 7.2 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; mobile phase = ethyl acetate-hexanes (1:1); R_f = 0.6.

Step f:

3-[3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenyl]-2-oxopropylphosphonic acid was prepared from methyl-3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenoxy)phenylacetate following the same procedure as described in compound 21: mp: 80-82 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.85 (s, 2 H), 6.51 (d, J = 2.1 Hz, 1 H), 6.48 (d, J = 8.4 Hz, 1 H), 6.14 (dd, J = 3.0, 9.0 Hz, 1 H), 4.80 (s, 2 H), 3.80 (s, 2 H), 3.20-3.10 (m, 1 H), 2.99 (d, J = 22.5 Hz, 1 H), 1.97 (s, 6 H), 1.03 (d, J = 6.9 Hz, 6 H); LC-MS m/z = 393 $[C_{20}H_{25}O_6P + H]^+$; HPLC conditions: ODSAQ AQ-303-5 column; mobile phase = CH_3OH:5%TFA(7:3) flow rate = 1.0 mL/min; detection = UV @ 254 nm

retention time in min: 11.19; Anal Calcd for ($C_{20}H_{25}O_6P$ + 0.2 CH_2Cl_2): C, 58.82; H, 6.22. Found: C, 58.75; H, 6.30.

Example 33:

Compound 33: [3,5-dimethyl-4-(4'-Hydroxy-3'-*iso*-propyl-phenyl)methoxymethyl]-phenoxy]methylphosphonic acid

Step a:

To a solution of (2,6-dimethyl-4-triisopropylsilanyloxyphenyl)-(3-*iso*-propyl-4-methoxymethoxyphenyl)methanol (1.60 g, 3.29 mmol, G. Chiellini *et al. Biorg. Med. Chem. Lett.* **2000,** *10,* 2607) in THF (30.0 mL) at 0 °C was added TBAF (4.93 mL, 4.93 mmol, 1.0 M solution in THF). The reaction mixture was stirred at room temperature for 60 min, diluted with diethyl ether (10.0 mL) and washed with water (20 mLx2). The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:4) to afford 3,5-dimethyl-4-[(3'-*iso*-propyl-4'-methoxymethoxyphenyl)-hydroxymethyl]phenol as a white solid (1.00 g, 92%): ^1H NMR (300 MHz, DMSO-d_6): δ 9.05 (s, 1 H), 7.17 (m, 1 H), 6.90 (m, 1 H), 6.77 (m, 1 H), 6.37 (s, 2 H), 5.97 (d, J = 6.0 Hz, 1 H), 5.51 (d, J = 6.0 Hz, 1 H) 5.15 (s, 2H), 3.36 (s, 3 H), 3.23 (m, 1 H), 2.10 (s, 6 H), 1.16 (m, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (4:1); R_f = 0.17.

Step b:

To a mixture of 3,5-dimethyl-4-[(3'-*iso*-propyl-4'-methoxymethoxyphenyl)-hydroxymethyl]phenol (0.380 g, 1.15 mmol) in DMF (10.0 mL) at 0 °C was added Cs_2CO_3 (1.87 g, 5.75 mmol). After 5 min, trifluoromethanesulfonic acid diethoxyphosphorylmethyl ester (0.24 g, 1.15 mmol) was added. The reaction mixture was stirred at room temperature for 16 h, quenched with 1 N HCl, diluted with ethyl acetate and extracted with water (10 mLx4). The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:4) to afford diethyl [3,5-dimethyl-4-[(3'-*iso*-propyl-4'-methoxymethoxyphenyl)-hydroxymethyl]phenoxy]methylphosphonate as an oil (0.41 g, 74%): ^1H NMR (300 MHz, DMSO-d_6): δ 7.20 (m, 1 H), 6.92 (m, 1 H), 6.78 (m, 1 H), 6.67 (s, 2 H), 6.03 (d, J = 3.0 Hz, 1 H), 5.64 (d, J = 3.0 Hz, 1 H), 5.18 (s, 2H), 4.38 (d, J = 9.0 Hz, 2 H), 4.11 (m, 4 H), 3.38 (s, 3 H), 3.25 (m, 1 H), 2.19 (s, 6 H), 1.24 (m, 6 H), 1.16 (m, 6 H); TLC

conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (6:4); R_f = 0.35.

Step c:

To a solution of diethyl [3,5-dimethyl-4-[(3'-*iso*-propyl-4'-methoxymethoxyphenyl)-hydroxymethyl]phenoxy]methylphosphonate (0.200 g, 0.42 mmol) in MeOH (6.0 mL) at 0 °C was added 2 M HCl (2.1 mL, 4.20 mmol). The reaction mixture was stirred at 0 °C for 3 h and at room temperature for 16 h. The reaction mixture was diluted with ethyl acetate (10 .0 mL) and washed with water (20 mLx2). The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:1) to afford diethyl [3,5-dimethyl-4-[(4'-hydroxy-3'-*iso*-propylphenyl)methoxymethyl]phenoxy]methylphosphonate as an oil (0.125 g, 69%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.16 (s, 1 H), 7.03 (s, 1 H), 6.71 (s, 2 H), 6.59 (m, 2 H), 5.63 (s, 2 H), 4.41 (d, J = 15.0 Hz, 2 H), 4.11 (m, 4 H) 3.20 (s, 3H), 2.17 (s, 6 H), 1.21 (m, 6 H), 1.11 (m, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (1:1); R_f = 0.50.

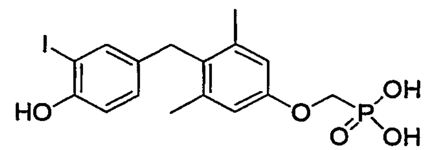
Step d:

To a solution of diethyl [3,5-dimethyl-4-[(4'-hydroxy-3'-*iso*-propylphenyl)methoxymethyl]phenoxy]methylphosphonate (0.065 g, 0.15 mmol) and 1,1,1,3,3,3- hexamethyldisilazane (0.38 mL, 1.80 mmol) in CH_2Cl_2 (3.0 mL) at -30 °C was added bromotrimethylsilane (0.12 mL, 0.90 mmol). The reaction mixture was stirred at room temperature 16 h and the solvent was removed under reduced pressure. The residue was treated with acetonitrile-water (4:1, 5.0 mLx3) and soncicated. The solvent was removed under reduced pressure and the residue was dissolved in 1 M NaOH (5 mL). The aqueous solution was extracted with ethyl acetate (5mLx2) and acidified with 2 M HCl. The mixture was diluted with ethyl acetate and washed several times with water. The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure to afford the title compound as a red powder (0.035 g, 62%): ^{1}H NMR (300 MHz, D_2O): δ 7.03 (s, 1 H), 6.78-6.67 (m, 4 H), 6.14 (s, 1 H), 4.02 (d, J = 10.5 Hz, 2 H), 3.21 (s, 3 H), 2.09 (s, 6 H), 1.01 (m, 6 H); HPLC conditions: Column = 3 Chromolith SpeedRODs RP-18e, 100×4.6 mm; Mobile phase = Solvent A (Acetonitrile) = HPLC grade acetonitrile; Solvent B (buffer) = 20 mM ammonium phosphate buffer

(pH 6.1, 0.018 M $NH_4H_2PO_4$/0.002 M $(NH_4)_2HPO_4$) with 5% acetonitrile. Flow rate = 4 mL/min; UV@ 255 nm. Retention time in minutes. (rt = 5.70, 93% purity).

Example 34:

Compound 34: [3,5-dimethyl-4-(4'-hydroxy-3'-iodobenzyl)phenoxy]methylphosphonic acid



Step a

To a mixture of diethyl [3,5- dimethyl-4-(4'-methoxymethoxybenzyl)phenoxy]methylphosphonate (0.26 g, 0.61 mmol, prepared from commercially available 4-bromophenol according to the procedure described in compound 7) in methanol (3.0 mL) at 0 °C was added 2 N HCl (1.0 mL). The reaction mixture was stirred at room temperature for 24 h, quenched with water (10.0 mL) and extracted with ethyl acetate (10 .0 mL). The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure to afford diethyl [3,5- dimethyl-4-(4'-hydroxybenzyl)phenoxy]methylphosphonate (0.22 g, 95%) as colorless oil: ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.11 (s, 1 H), 6.60-6.80 (m, 6 H), 4.35 (d, J = 14.7 Hz, 2 H), 4.11 (m, 4 H), 3.80 (s, 2 H), 2.15 (s, 6 H), 1.25 (t, J = 10.5 Hz, 2 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (1:1); R_f = 0.40.

[3,5-Dimethyl-4-(4'-hydroxy-3'-iodobenzyl)phenoxy]methylphosphonic acid was prepared from diethyl [3,5-dimethyl-4-(4'-hydroxybenzyl)phenoxy]methylphosphonate according to the procedure described in compound 2 steps f and g: ^{1}H NMR (300 MHz, CD_3OD): δ 7.27 (d, J = 2.4 Hz, 1 H), 6.83 (dd, J = 8.1, 2.1 Hz, 1 H), 6.76 (s, 2 H), 6.72 (d, J = 8.1 Hz, 1 H), 4.23 (d, J = 10.2 Hz, 2 H), 3.91 (s, 2 H), 2.23 (s, 6 H); LC-MS m/z = 449 $[C_{16}H_{18}IO_5P + H]^+$; Anal Calcd for ($C_{16}H_{18}IO_5P$ + 0.7 H_2O): C, 41.70; H, 4.24. Found: C, 41.73; H, 4.56.

Example 35:

Compound 35: [3,5-dimethyl-4-(3'-carboxyl-4'-hydroxy-benzyl)phenoxy]methylphosphonic acid

Step a:

To the suspension of NaH (3.25 g, 0.135 mol) in DMF (150 mL) was added 4-hydroxy-benzaldehyde (15.0 g, 0.123 mol) in DMF (10 mL) at 0 °C, 5 min. later the reaction mixture became a cake. The heterogeneous mixture was stirred at 0 °C for 30 min. MOMCl (9.96 g, 0.123 mol) was added slowly and the reaction mixture was allowed to warm up to r.t. After stirring at r.t. for 16 h, the volatiles were removed under vacuum. The residue was partitioned between ethyl acetate and water and the water layer was further extracted with ethyl acetate. The combined ethyl acetate extracts were dried over $MgSO_4$, filtered and concentrated. The residue was purified by column chromatography on silica gel (ethyl acetate-hexanes;1:4) to afford 4-methoxymethoxy-benzaldehyde (19.0 g, 93%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 9.94 (s, 1H), 7.88 (m, 2H), 7.18 (m, 2H), 5.29 (s, 2H), 3.53 (s, 2H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:4); R_f= 0.86.

Step b:

To a solution of (4-bromo-3,5-dimethyl-phenoxy)triisopropylsilane (8.0 g, 23.30 mmol) in THF (50 mL) was added a solution of n-butyllithium (2.5 M in THF, 90 mL) at –78 °C. The heterogeneous mixture was stirred at –78 °C for 1 h A solution of 4-methoxymethoxy-benzaldehyde (3.09 g, 18.58 mmol) in THF (5 mL) was added and the mixture was stirred at –78 °C for 1 h then warmed up to r.t. The reaction was then diluted with ethyl acetate and water, the layers were separated and the aqueous layer was extracted with ethyl acetate. The combined organic extracts were dried ($MgSO_4$), filtered and concentrated to afford crude (2,6-dimethyl-4-triisopropylsilanyloxyphenyl)-(4-methoxymethoxyphenyl)methanol. Carried on to the next step without further purificaton.

Step c:

A degassed solution of crude (2,6-dimethyl-4-triisopropylsilanyloxyphenyl)-(4-methoxymethoxyphenyl)methanol (12.0 g, 26.84 mmol) and Pd/C (1.2 g) in EtOAc/HOAc (19/1) was stirred under an atmosphere of hydrogen (1 atm) at r.t. After 5 h, the catalyst was filtered through a pad of Celite, rinsed with ethyl acetate and the combined filtrates concentrated under reduced pressure. The residue was purified by

column chromatography on silica gel (ethyl acetate-hexanes;1:9) to afford 4-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-methoxymethoxybenzene (4.0 g, 41.5% for two steps): ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.93 (s, 4H), 6.63 (s, 2H), 5.16 (s, 2H), 3.94 (s, 2H), 3.50 (m, 3H), 1.58 (s, 6H), 1.29 (m, 3H), 1.13 (m, 18H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:19); R_f = 0.80.

Step d:

To a solution of 4-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-methoxymethoxybenzene (2.0 g, 4.66 mmol) in ether was added TMEDA (1.05 mL, 6.99 mmol), followed by nBuLi (2.5 M in THF, 2.8 mL) at –20 °C. The reaction mixture was warmed up to 0 °C and stirred for 1 h DMF (0.72 mL, 9.32 mmol) was then added and after stirring at 0 °C for 2 h, the reaction mixture was quenched with a saturated solution of NH_4Cl and diluted with EtOAc. The water layer was extracted with EtOAc and the combined organic extracts were dried ($MgSO_4$), filtered and concentrated to give the crude product 5-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-2-methoxymethoxy-benzaldehyde (2.1 g, 98%): ^{1}H NMR (300 MHz, d6-DMSO): δ 10.33 (s, 1H), 7.24 (m, 3H), 6.58 (s, 2H), 5.31 (s, 2H), 3.91 (s, 2H), 3.33 (s, 6H), 1.23 (m, 3H), 1.06 (m, 18H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); R_f = 0.55.

Step e:

To a solution of 5-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-2-methoxymethoxy-benzaldehyde (1.4 g, 3.07 mmol) in THF (15 mL) was added TBAF (1 M, 3.68 mL) at 0 °C. After stirring at r.t. for 2 h, the reaction mixture was diluted with EtOAc and water. The water layer was extracted with EtOAc and the combined organic extracts were dried ($MgSO_4$), filtered and concentrated. The residue was purified by column chromatography on silica gel (ethyl acetate-hexanes; 1:9) to afford 5-(4-hydroxy-2,6-dimethylbenzyl)-2-methoxymethoxybenzaldehyde (590 mg, 64% for two steps): ^{1}H NMR (200 MHz, $CDCl_3$): δ 10.45 (s, 1H), 7.54 (s, 1H), 7.27 (m, 1H), 7.09 (m, 1H), 6.56(s, 2H), 5.25 (s, 2H), 3.92 (s, 2H), 3.50 (s, 3H), 2.16 (s, 6H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); R_f = 0.68.

Step f:

To a solution of 5-(4-hydroxy-2, 6-dimethylbenzyl)-2-methoxymethoxybenzaldehyde (590 mg, 1.97 mmol) in DMF (10 mL) was added Cs_2CO_3 (3.2 g, 9.83 mmol), followed by trifluoromethanesulfonic acid diethoxy-

phosphorylmethyl ester (649 mg, 2.16 mmol) at r.t. After stirring at r.t. for 16 h, the reaction mixture was concentrated under reduced pressure and the residue was partitioned between EtOAc and water. The water layer was extracted with EtOAc and the combined organic extracts were dried ($MgSO_4$), filtered and concentrated. The residue was purified by column chromatography on silica gel (ethyl acetate-hexanes; 1:1) to afford diethyl [4-(3'-formyl-4'-methoxymethoxybenzyl)-3,5-dimethylphenoxy]methylphosphonate (650 mg, 72%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 10.42 (s, 1H), 7.51 (s, 1H), 7.09 (m, 2H), 6.67 (s, 2H), 5.25 (s, 2H), 4.26 (m, 6H), 3.94 (s, 2H), 3.50 (s, 3H), 2.19 (s, 6H), 1.37 (m, 6H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:1); R_f = 0.55.

Step g:

To a solution of [4-(3'-formyl-4'-methoxymethoxybenzyl)-3,5-dimethylphenoxy]methylphosphonate (650 mg, 1.44 mmol) in THF (1.0 mL) at r.t. was added a solution of NaH_2PO_4 (52 mg, 0.43 mmol) in water (0.2 mL), 30% H_2O_2 (30%, 0.16 mL) followed by a solution of sodium chlorite (245 mg, 2.17 mmol) in water (1.0 mL). After stirring at r.t. for 30 min., the reaction mixture was diluted with EtOAc and water. The water layer was extracted with EtOAc and the combined organic extracts were washed with water, brine, dried ($MgSO_4$), filtered and concentrated to afford diethyl [3,5-dimethyl-4-(3'-carboxyl-4'-hydroxybenzyl)phenoxy]methylphosphonate as yellow solid (585 mg, 86.9%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.91 (m, 1H), 7.11 (m, 2H), 6.68 (s, 2H), 4.25 (m, 6H), 3.96 (s, 2H), 3.54 (s, 3H), 2.19 (s, 6H), 1.37 (m, 6H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = MeOH-ethyl acetate (1:9); R_f = 0.2.

Step h:

To the solution of diethyl [3,5-dimethyl-4-(3'-carboxyl-4'-hydroxy-benzyl)phenoxy]methylphosphonate (100 mg, 0.21 mmol) in CH_2Cl_2 (10 mL) was added TMSBr (0.28 mL, 2.10 mmol) at r.t. After stirring at r.t. for 16 h, the reaction mixture was concentrated and the residue was suspended in MeOH. After stirring for 2 h, the volatiles were removed and the residue was azeotropped with CH_2Cl_2 twice to provide [3,5-dimethyl-4-(3'-carboxyl-4'-hydroxybenzyl)phenoxy]methylphosphonic acid as a white solid (48 mg, 61.5%): mp. >200 °C; ^{1}H NMR (200 MHz, DMSO-d_6): δ 7.38 (d, J = 2.1 Hz, 1H), 7.17 (m, 1H), 6.87 (d, J = 8.4 Hz, 1H), 6.74 (s, 2H), 4.06 (d, J = 10.2 Hz, 2H), 3.89 (s, 2H), 2.18 (s, 6H). mp > 200, LC-MS m/z = 367 $[C_{17}H_{19}O_7P + H]^+$; Anal. Calcd for ($C_{17}H_{19}O_7P$ + 0.4 H_2O): C, 54.67; H, 5.34. Found: C, 54.57; H, 5.60.

Example 36:

Compound 36: [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylcarbamoylbenzyl)-phenoxy]methylphosphonic acid

Step a:

To a solution of diethyl [3,5-dimethyl-4-(3'-carboxyl-4'-hydroxy-benzyl)phenoxy]methylphosphonate (compound 35, step f; 122 mg, 0.262 mmol) in DMF (5.0 mL) was added EDCI (60 mg, 0.314 mmol), HOAT (53 mg, 0.393 mmol), diisopropylethylamine (0.23 mL, 1.31 mmol) and isopropylamine (0.03 mL, 0.288 mmol). After stirring at r.t. for 16 h, the reaction mixture was concentrated under reduced pressure and the residue was partitioned between EtOAc and a saturated solution of $NaHCO_3$. The aqueous layer was extracted with EtOAc and the combined organic extracts were washed with water, brine, dried ($MgSO_4$), filtered and concentrated. The residue was purified by column chromatography on silica gel (ethyl acetate-hexanes; 1:1) to afford diethyl [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylcarbamoylbenzyl)-phenoxy]methylphosphonic acid as yellowish liquid (40 mg, 30%). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:1); R_f = 0.45.

Step b:

The title compound was prepared by the procedure described for the synthesis of compound 35, step f as an off-white solid (30 mg, 93.7%); mp.: 90 °C, dec; ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.52 (d, J = 7.5 Hz, 1H), 7.77 (d, J = 1.5 Hz, 1H), 6.73(m, 4H), 4.14 (m, 1H), 4.06 (d, J = 10.2 Hz, 2H), 3.88 (s, 2H), 2.18 (s, 6H), 1.21 (d, J = 6.9 Hz, 6H). mp: decomposed at 90, LC-MS m/z = 408 $[C_{20}H_{26}NO_6P + H]^+$; Anal. Calcd for ($C_{20}H_{26}NO_6P$ + 0.26 acetone + 1.4 HBr): C, 46.58; H, 5.45; N, 2.61. Found: C, 46.49; H, 5.84; N, 2.93.

Example 37:

Compound 37: [3,5-dimethyl-4-(4'-hydroxy-3'-phenethylcarbamoylbenzyl)phenoxy]methylphosphonic acid

Step a:

5-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-2-methoxymethoxybenzaldehyde (example 35; step e) was transformed into 5-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-2-methoxymethoxybenzoic acid by the procedure used for the syntheis of compound 35, step g: yellow solid (360 mg, 86.9%);

^{1}H NMR (200 MHz, $CDCl_3$): δ 7.94 (s, 1H), 7.08 (m, 2H), 6.60 (s, 2H), 5.36 (s, 2H), 3.95 (s, 2H), 3.53 (s, 3H), 2.14 (s, 6H), 1.26 (m, 3H), 1.14 (m, 18H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = MeOH-ethyl acetate (1:9) ; R_f= 0.45.

Step b:

N-phenethyl 5-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-2-methoxymethoxybenzamide was prepared by the procedure used for the synthesis of compound 36, step a: colorless liquid (330 mg, 75%); ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.05 (d, J = 2.4 Hz, 1H), 7.84 (m, 1H), 7.82 (m, 5H), 6.97 (d, J = 9.0 Hz, 1H), 6.64(m, 1H), 6.61 (s, 2H), 5.01 (s, 2H), 3.97 (s, 2H), 3.82 (m, 2H), 3.30 (s, 3H), 2.97 (m, 2H), 2.18 (s, 6H), 1.28 (m, 3H), 1.14 (m, 18H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:1); R_f= 0.55.

Step c:

N-phenethyl 5-(2,6-dimethyl-4-hydoxybenzyl)-2-methoxymethoxybenzamide was prepared by the procedure used for the synthesis of compound 35, step e: (170 mg, 70%); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:1); R_f= 0.45.

Step d:

Diethyl [3,5-dimethyl-4-(4'-methoxymethoxy-3'-phenethylcarbamoylbenzyl)phenoxy]methylphosphonate was prepared by the procedure used for the synthesis of compound 35, step f: (185 mg, 80%); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.98 (d, J = 2.1 Hz, 1H), 7.85 (m, 1H), 7.32 (m, 5H), 7.01 (d, J = 5.4 Hz, 1H), 6.91(m, 1H), 6.69 (s, 2H), 4.29 (m, 4H), 3.98 (s, 2H), 3.81 (m, 2H), 3.31 (s, 3H), 2.96 (m, 2H), 2.22 (s, 6H), 1.41 (m, 6H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:1); R_f= 0.52.

Step e:

The title compound was prepared by the procedure used for the synthesis of compound 35, step h: white solid (40 mg, 48.8%): mp.: 100 °C, dec; ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.85 (m, 1H), 7.67 (d, J = 2.1 Hz, 1H), 7.32 (m, 5H), 6.86 (m, 2H), 6.78(s, 2H), 4.10 (d, J = 10.5 Hz, 2H), 3.91 (s, 2H), 3.57 (m, 2H), 2.92 (m, 2H), 2.24 (s, 6H). mp: decomposed at 100, LC-MS m/z = 470 $[C_{25}H_{28}NO_6P + H]^+$; Anal. Calcd for ($C_{25}H_{28}NO_6P$ + 0.9 HBr): C, 55.37; H, 5.37; N,

Example 38:

Compound 38: [4-(3'-benzyl-4'-hydroxy-benzyl)-3,5-dimethylphenoxy]methylphosphonic acid

Step a:

To a stirring solution of bromobenzene (0.45 g, 2.89 mmol) in THF (20 mL) at –78 °C was added *n*-BuLi (1.16 mL, 2.5 M in hexanes). The mixture was stirred at –78 °C for 1 h and a solution of 5-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-2-methoxymethoxybenzaldehyde (example 35; step e, 1.2 g, 2.63 mmol) was added. The reaction mixture was stirred at –78 °C for 1 h, allowed to warm to room temperature and stirred for 1 h. The reaction mixture was quenched with saturated NH_4Cl and diluted with diethyl ether. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford [5-(2,6-dimethyl-4-triisopropylsilanyloxy-benzyl)-2-methoxymethoxy-phenyl]-phenyl-methanol as an yellow oil (1.4 g, 99.6%): ^1H NMR (200 MHz, DMSO-d_6): δ 7.23 (m, 6 H), 6.85 (d, J = 8.8 Hz, 1 H), 6.68 (m, 1 H), 6.56 (s, 2 H), 5.92 (d, J = 4.0 Hz, 1 H), 5.62 (d, J = 4.0 Hz, 1 H), 5.10 (q, J = 4.0 Hz, 2 H), 3.84 (s, 2 H), 3.23 (s, 3 H), 2.11 (s, 6 H), 1.23 (m, 3 H), 1.06 (d, J = 6.4 Hz, 18 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 15% ethyl acetate in hexanes; R_f = 0.50.

Step b:

To a solution of [5-(2,6-dimethyl-4-triisopropylsilanyloxy-benzyl)-2-methoxymethoxy-phenyl]-phenyl-methanol (1.4 g, 2.6 mmol) in ethyl acetate (20 mL) and acetic acid (1.5 mL) was added Pd/C (0.15 g). The mixture was stirred under H_2 atmosphere for 16 h. The mixture was filtered through a celite plug. The solvent was removed under reduced pressure. The residue was dissolved in CH_2Cl_2 (26 mL), ethyl-diisopropyl-amine (0.69 mL, 3.95 mmol) and chloromethyl methyl ether (0.26 mL, 3.42 mmol) were added. The reaction mixture was refluxed for 16 h and quenched with water. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (15:75) to afford [4-(3'-benzyl-4'-methoxymethoxy-benzyl)-3,5-dimethyl-phenoxy]-triisopropylsilane as an oil (0.9 g, 66%): ^1H NMR (200 MHz, DMSO-d_6): δ 7.20 (m, 5 H), 6.90 (d, J = 8.4 Hz, 1 H), 6.79 (s, 1 H), 6.70 (m, 1 H), 6.54 (s, 2 H), 5.12 (s, 2 H), 3.83 (s, 2 H), 3.81 (s, 2 H), 3.25 (s, 3 H), 2.09 (s, 6 H), 1.23

(m, 3 H), 1.06 (d, J = 6.6 Hz, 18 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 15% ethyl acetate in hexanes; R_f = 0.66.

Step c:

To a stirring solution of [4-(3'-benzyl-4'-methoxymethoxy-benzyl)-3,5-dimethyl-phenoxy]-triisopropylsilane (0.9 g, 1.73 mmol) in THF (20 mL) at room temperature was added tetrabutylammonium fluoride (2.3 mL, 1.0 M in THF). The reaction mixture was stirred at room temperature for 1 h, diluted with diethyl ether and washed with water (30 mLx2). The solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford 4-(3'-benzyl-4'-methoxymethoxy-benzyl)-3,5-dimethyl-phenol as a light yellow oil (0.6 g, 86%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 8.98 (s, 1 H), 7.16 (m, 5 H), 6.87 (m, 2 H), 6.70 (m, 1 H), 6.43 (s, 2 H), 5.12 (s, 2 H), 3.85 (s, 2 H), 3.76 (s, 2 H), 3.24 (s, 3 H), 2.06 (s, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 20% ethyl acetate in hexanes; R_f = 0.34.

Step d:

Diethyl [4-(3'-benzyl-4'-methoxymethoxy-benzyl)-3,5-dimethyl-phenoxy]methylphosphonate was prepared by the procedure used for the synthesis of compound 35, step f as a light yellow oil (0.09 g, 64%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 7.22 (m, 5 H), 6.87 (m, 2 H), 6.70 (m, 3 H), 5.12 (s, 2 H), 4.35 (d, J = 10 Hz, 2 H), 4.11 (m, 4 H), 3.85 (s, 2 H), 3.82 (s, 2 H), 3.24 (s, 3 H), 2.13 (s, 6 H), 1.25 (t, J = 7 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 40% ethyl acetate in hexanes; R_f = 0.27.

Step e:

The title compound was prepared by the procedure used for the synthesis of compound 35, step h as a white foam (32 mg, 44%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.14 (s, 1 H), 7.21 (m, 5 H), 6.67 (m, 4 H), 6.56 (m, 1 H), 4.02 (d, J = 10.2 Hz, 2 H), 3.78 (s, 2 H), 3.75 (s, 2 H), 2.12 (s, 6 H); LC-MS m/z = 413 [$C_{23}H_{25}O_5P$ + H]$^+$; Anal Calcd for ($C_{23}H_{25}O_5P$ +0.2 Et_2O+0.6 H_2O): C, 65.26; H, 6.49. Found: C, 65.07; H, 6.38.

Example 39:

Compound 39: [3,5-dimethyl-4-[3'-(4-fluoro-benzoyl)-4'-hydroxy-benzyl]phenoxy]methylphosphonic acid

Step a:

[5-(2,6-dimethyl-4-triisopropylsilanyloxy-benzyl)-2-methoxymethoxy-phenyl]-(4-fluoro-phenyl)-methanol was prepared by the procedure used for the synthesis of example 38, step a as an oil (0.68 g, 56%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 7.26 (m, 3 H), 7.06 (m, 2 H), 6.85 (d, J = 8.4 Hz, 1 H), 6.71 (m, 1 H), 6.56 (s, 2 H), 5.91 (d, J = 4.0 Hz, 1 H), 5.68 (d, J = 4.0 Hz, 1 H), 5.10 (q, J = 3.4 Hz, 2 H), 3.84 (s, 2 H), 3.22 (s, 3 H), 2.11 (s, 6 H), 1.23 (m, 3 H), 1.06 (d, J = 6.2 Hz, 18 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 15% ethyl acetate in hexanes; R_f = 0.26.

Step b:

To a stirring solution of [5-(2,6-dimethyl-4-triisopropylsilanyloxy-benzyl)- 2-methoxymethoxy-phenyl]-(4-fluoro-phenyl)-methanol (0.68 g, 1.2 mmol) in dichloromethane (25 mL) at 0 °C was added Dess-Martin periodinane (3.9 mL, 0.48 M solution in CH_2Cl_2). The reaction mixture was stirred at room temperature for 4 h, concentrated, diluted with ethyl acetate. To the solution was added a solution of $Na_2S_2O_3$ pentahydrate (50 mg) in 60 mL saturated $NaHCO_3$. After 15 min, the organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford crude 5-(2,6-dimethyl-4-triisopropylsilanyloxy-benzyl)-(4-fluorobenzoyl)-2-methoxymethoxy-phenyl as an oil (0.68 g, 100%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 7.72 (m, 2 H), 7.33 (m, 2 H), 7.12 (m, 2 H), 6.86 (s, 1 H), 6.56 (s, 2 H), 5.04 (s, 2 H), 3.92 (s, 2 H), 3.14 (s, 3 H), 2.13 (s, 6 H), 1.21 (m, 3 H), 1.03 (d, J = 6.2 Hz, 18 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 20% ethyl acetate in hexanes; R_f = 0.26.

Step c:

To a stirring solution of 4-(2',6'-dimethyl-4'-triisopropylsilanyloxy-benzyl)-2-(4-fluorobenzoyl)-phenol was prepared by the procedure used for the synthesis of example 35 step c as a white solid (0.42 g, 86%): mp 140–142 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.05 (s, 1 H), 7.78 (m, 2 H), 7.36 (m, 2 H), 7.13 (m, 2 H), 6.95 (d, J = 1.5 Hz, 1 H), 6.47 (s, 2 H), 5.05 (s, 2 H), 3.90 (s, 2 H), 3.15 (s, 3 H), 2.12 (s, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 20% ethyl acetate in hexanes; R_f = 0.63.

Step d:

Diethyl [3,5-dimethyl-4-[3'-(4-fluoro-benzoyl)-4'-hydroxy-benzyl]phenoxy]methylphosphonate was prepared by the procedure used for the synthesis of example 35 step f as a light yellow oil (0.054 g, 19%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.76 (m, 2 H), 7.36 (m, 2 H), 7.13 (m, 2 H), 6.94 (d, J = 1.5 Hz, 1 H), 6.77 (s, 2 H), 5.05 (s, 2 H), 4.36 (d, J = 9.6 Hz, 2 H), 4.11 (m, 4 H), 3.95 (s, 2 H), 3.15 (s, 3 H), 2.20 (s, 6 H), 1.25 (m, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 67% ethyl acetate in hexanes; R_f = 0.37.

Step d:

The title compound was prepared by the procedure used for the synthesis of example 35 step h as a yellow foam (22 mg, 50%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 10.14 (s, 1 H), 7.74 (m, 2 H), 7.31 (m, 2 H), 7.03 (m, 1 H), 6.92 (m, 2 H), 6.69 (s, 2 H), 4.02 (d, J = 10.6 Hz, 2 H), 3.87 (s, 2 H), 2.16 (s, 6 H); LC-MS m/z = 445 [$C_{23}H_{22}FO_6P$ + H]$^+$; Anal Calcd for ($C_{23}H_{22}FO_6P$ +0.2 Et_2O+0.3 CF_3COOH): C, 59.39; H, 4.96. Found: C, 59.62; H, 4.64.

__Example 40:__

__Compound 40: [3,5-dimethyl-4-[3'-(4-fluoro-benzyl)-4'-hydroxy-benzyl]phenoxy]methylphosphonic acid__

Step a:

To a stirring solution of diethyl [3,5-dimethyl-4-[3'-(4-fluoro-benzyl)-4'-hydroxy-benzyl]phenoxy]methylphosphonic acid (0.13 g, 0.24 mmol) in MeOH (8 mL) at 0 °C was added $NaBH_4$ (90 mg, 2.4 mmol). The reaction mixture was stirred at room temperature for 16 h. The solvent was removed under reduced pressure and the residue was partitioned between ethyl acetate and water. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford diethyl [3,5-dimethyl-4-[3'-(4-fluorophenyl-hydroxymethyl)-4'-hydroxy-benzyl]phenoxy]methylphosphonic acid as an oil (0.13 g, 100%). This crude product was dissolved in CH_2Cl_2 (10 mL) and Et_3SiH (0.38 mL, 2.4 mmol) and TFA (0.18 mL, 2.4 mmol) were added. The reaction mixture was stirred at room temperature for 16 h. The solvent was removed under reduced pressure and the residue was partitioned between ethyl acetate and saturated $NaHCO_3$. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate to afford diethyl [3,5-

dimethyl-4-[3'-(4-fluoro-benzyl)-4'-hydroxy-benzyl]phenoxy]methylphosphonate as an oil (80 mg, 69%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.18 (s, 1 H), 7.13 (m, 4 H), 6.67 (m, 5 H), 4.33 (d, J = 10 Hz, 2 H), 4.11 (m, 4H), 3.76 (s, 4 H), 2.12 (s, 6H), 1.25 (t, J = 7 Hz, 6 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate; R_f = 0.5.

Step b:

The title compound was prepared by the procedure used for the synthesis of example 35 step h as a yellow solid (60 mg, 85%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.11 (s, 1 H), 7.13 (m, 4 H), 6.63 (m, 5 H), 4.01 (d, J = 10.2 Hz, 2 H), 3.76 (s, 4 H), 2.12 (s, 6 H); LC-MS m/z = 431 [$C_{23}H_{24}FO_5P$ + H]$^+$; Anal Calcd for ($C_{23}H_{24}FO_5P$ + 0.6 H_2O + 0.2 Et_2O): C, 62.68; H, 6.01. Found: C, 62.31; H, 6.16; mp: 169 - 171 °C.

Example 41:

Compound 41: [3,5-dimethyl-4-[3'-benzyl-4'-hydroxy-benzyl]benzoyl]methylphosphonic acid

Step a:

To a solution of 4-(3'-benzyl-4'-methoxymethoxy-benzyl)-3,5-dimethyl-phenol (example 38, step c, 0.5 g, 1.38 mmol) and DMAP (0.67 g, 5.52 mmol) in CH_2Cl_2 (20 mL) at 0 °C was slowly added trifluoromethanesulfonyl anhydride (0.35 mL, 2.1 mmol). The reaction mixture was stirred at 0 °C for 2 h and quenched by water (10 mL). The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford 4-(3'-benzyl-4'-methoxymethoxy-benzyl)-3,5-dimethyl-phenyl trifluoromethanesulfonate as an oil (0.5 g, 73%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.14 – 7.28 (m, 7 H), 6.94 (d, J = 8.4 Hz, 1 H), 6.85 (d, J = 2.4 Hz, 1 H), 6.70 (m, 1 H), 5.15 (s, 2 H), 3.94 (s, 2 H), 3.88 (s, 2 H), 3.27 (s, 3 H), 2.24 (s, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (15:75); R_f = 0.55.

Step b:

To a solution of 4-(3'-benzyl-4'-methoxymethoxy-benzyl)-3,5-dimethyl-phenyl trifluoromethanesulfonate (0.5 g, 1 mmol) in DMF (8 mL) in a bomb apparatus was added MeOH (0.82 mL, 20 mmol), $Pd(OAc)_2$ (23 mg, 0.1 mmol), bis-(diphenyphosphino)propane (42 mg, 0.1 mmol) and TEA (0.28 mL, 2 mmol). 60 psi of CO was then infused and the reaction mixture was stirred at 90 °C for 16 h. The cooled bomb was vented and the reaction mixture was poured into cold 1N HCl, extracted with

EtOAc twice, the combined EtOAc were washed with brine, dried over $MgSO_4$, filtrated and concentrated. The residue was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (15:75) to afford methyl 4-(3'-benzyl-4'-' methoxymethoxy-benzyl)-3,5-dimethyl-benzoate as a yellow oil (360 mg, 88%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.66 (s, 2 H), 7.16 (m, 5 H), 6.90 (m, 2 H), 6.71 (m, 1 H), 5.15 (s, 2 H), 3.98 (s, 2 H), 3.87 (s, 2 H), 3.85 (s, 3 H), 3.26 (s, 3H), 2.25 (s, 6H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (15:75); R_f= 0.50.

Step c:

To a stirring solution of diethyl methylphosphonate (0.39 mL, 2.67 mmol) in THF (10 mL) at –78 °C was added *n*-BuLi (2.5 M in hexanes, 1.07 mL), the reaction mixture was stirred at –78 °C for 1 h, then methyl 4-(3'-benzyl-4'-methoxymethoxy-benzyl)-3,5-dimethyl-benzoate (360 mg, 0.89 mmol) in THF (10 mL) was added at the same temperature. The reaction mixture was stirred at –78 °C for 1.5 h, then at room temperature for 1 h. The reaction mixture was quenched with saturated NH_4Cl and diluted with diethyl ether. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel, eluting with ethyl acetate to afford diethyl [3,5-dimethyl-4-[3'-benzyl-4'-hydroxy-benzyl]benzoyl]methylphosphonate as a light yellow oil (350 mg, 75%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.72 (s, 2 H), 7.16 (m, 5 H), 6.92 (m, 2 H), 6.71 (m, 1 H), 5.14 (s, 2 H), 4.04 (m, 6 H), 3.99 (s, 2 H), 3.82 (d, J = 22.2 Hz, 2 H), 3.26 (s, 3H), 2.27 (s, 6H), 1.19 (t, J = 7.5 Hz, 6 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:1); R_f= 0.35.

Step d:

The title compound was prepared by the procedure described for the synthesis of example 35, step h as a white foam (55 mg, 88%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.21 (s, 1 H), 7.66 (s, 2 H), 7.21 (m, 5 H), 6.65 (m, 2 H), 6.55 (m, 1 H), 3.89 (s, 2 H), 3.79 (s, 2 H), 3.45 (d, J = 22.8 Hz, 2 H), 2.16 (s, 6 H); LC-MS m/z = 425 [$C_{24}H_{25}O_5P$ + H]$^+$; Anal Calcd for ($C_{24}H_{25}O_5P$ +1.6 H_2O): C, 63.60; H, 6.27. Found: C, 63.87; H, 6.43.

Using the appropriate starting material, compounds 41-1 to 41-3 were prepared in an analogous manner to that described for the synthesis of compound 41.

Compound 41-1: 2-[3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propyl-benzyl)phenyl]-2-oxo-ethylphosphonic acid

The title compound was prepared from 3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propyl-benzyl)- phenol (compound 27, step e) by the procedure described for the synthesis of compound 41 as a white solid (106 mg, 81.5%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.70 (s, 2H), 7.10 (m, 1H), 6.98 (m, 1H), 6.65 (m, 1H), 4.00 (s, 2H), 3.48 (d, J = 22.4 Hz, 2H), 3.09 (m, 1H), 2.26 (s, 6H), 1.17 (d, J = 7.0 Hz, 6H). mp = 138~140, LC-MS m/z = 379 [$C_{20}H_{24}FO_4P$ + H]$^+$; Anal. Calcd for ($C_{20}H_{24}FO_4P$): C, 63.49; H, 6.39. Found: C, 63.40; H, 6.63.

Compound 41-3: 2-[3,5-dichloro-4-(4-fluoro-*iso*-propyl-benzyl)-phenyl]-2-oxo-ethylphosphonic acid

3,5-Dichloro-4- (4-fluoro-3-*iso*-propyl-benzyl)-phenol, intermediate for the synthesis of compound 27-2, was transformed into the title compound by the procedure described for the synthesis of compound 41 to give a white solid (65 mg, 82%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.08 (s, 2H), 7.25 (m, 1H), 7.05 (m, 1H), 6.90 (m, 1H), 4.32 (s, 2H), 3.60 (d, J = 22.5 Hz, 2H), 3.12 (m, 1H), 1.20 (d, J = 6.9 Hz, 6H). mp = 132~134, LC-MS m/z = 417 [$C_{18}H_{18}Cl_2FO_4P$ + H]$^+$; Anal. Calcd for ($C_{18}H_{18}Cl_2FO_4P$): C, 51.57; H, 4.33. Found: C, 51.37; H, 4.65.

Example 42:

Compound 42: 2-[3,5-dimethyl-4-[3'-benzyl-4'-hydroxy-benzyl]phenyl]-ethylphosphonic acid

Step a:

To a stirring solution of diethyl [3,5-dimethyl-4-[3'-benzyl-4'-hydroxy-benzyl]benzoyl]methylphosphonate (example 41, step c, 0.27 g, 0.52 mmol) in MeOH (10 mL) at 0 °C was added $NaBH_4$ (78 mg, 2.1 mmol). The reaction mixture was stirred at room temperature for 4 h. The solvent was removed under reduced pressure and the residue was partitioned between ethyl acetate and water. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford diethyl 2-[4-(3'-benzyl-4'-methoxymethoxy-benzyl)-3,5-dimethyl-phenyl]-2-hydroxy-ethyl-phosphonate as an oil (0.27 g, 100%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.18 (m, 5 H), 7.03 (s, 2 H), 6.93 (m, 2 H), 6.70 (m, 1 H), 5.39 (d, J = 4.5 Hz, 1 H), 5.14 (s, 2 H), 4.80 (m, 1 H), 3.85

(m, 8 H), 3.26 (s, 3H), 2.18 (s, 6H), 1.19 (m, 6 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:1); R_f= 0.29.

Step b:

To a stirring solution of diethyl 2-[4-(3'-benzyl-4'-methoxymethoxy-benzyl)-3,5-dimethyl-phenyl]-2-hydroxy-ethyl-phosphonate (0.24 g, 0.46 mmol) in CH_2Cl_2 (10 mL) at room temperature was added Et_3SiH (0.34 mL, 2.1 mmol) and TFA (0.4 mL, 5.4 mmol). The reaction mixture was stirred at room temperature for 16 h. The solvent was removed under reduced pressure and the residue was partitioned between ethyl acetate and saturated $NaHCO_3$. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (3:1) to afford 2-[4-(3'-benzyl-4'-hydroxy-benzyl)-3,5-dimethyl-phenyl]- ethylphosphonate as an oil (55 mg, 26%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.16 (s, 1 H), 7.22 (m, 5 H), 6.91 (s, 2 H), 6.76(s, 1 H), 6.62 (m, 2 H), 4.00 (m, 4 H), 3.80 (s, 4 H), 2.68 (m, 2 H), 2.14 (s, 6H), 2.06 (m, 2H), 1.23 (m, 6 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:1); R_f= 0.33.

Step c:

The title compound was prepared by the procedure described for the synthesis of example 35, step h as a light yellow solid (28 mg, 58%): mp: 168–170 °C; ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.11 (s, 1 H), 7.19 (m, 5 H), 6.85 (s, 2 H), 6.63 (m, 3 H), 3.77 (s, 4 H), 2.66 (m, 2 H), 2.12 (s, 6 H), 1.76 (m, 2 H); LC-MS m/z = 411 $[C_{24}H_{27}O_4P + H]^+$; Anal Calcd for ($C_{24}H_{27}O_4P$ +1.6 H_2O): C, 68.14; H, 6.77. Found: C, 68.19; H, 6.55;.

<u>**Compound 42-1**: 2-[3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propyl-benzyl)phenyl]ethylphosphonic acid</u>

Step a:

Intermediate diethyl 2-[3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propyl-benzyl)phenyl]-2-oxo-ethylphosphonate for the synthesis of compound 41-1 was transformed into diethyl 2-[3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propyl-benzyl)phenyl]-2-hydroxy-ethylphosphonate by the procedure described for the synthesis of compound 42, step a to give a yellow liquid (580 mg, 96.2%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.12 (s, 2H), 6.99 (m, 1H), 6.84 (m, 1H), 6.66 (m, 1H), 5.09 (s, 1H), 4.19 (m, 4H), 4.01 (s, 1H), 3.18 (m,

1H), 2.22 (s, 6H), 2.20 (m, 2H), 1.36 (m, 6H), 1.25 (d, J = 6.4 Hz, 6H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (4:1); R_f = 0.58.

Step b:

A degased solution of diethyl 2-[3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propyl-benzyl)phenyl]-2-hydroxy-ethylphosphonate (500 mg, 1.15 mmol) and Pd/C (50 mg) in EtOH/HOAc(19/1) was stirred under 1 atmosphere of hydrogen at r.t. After 5h, the catalyst was filtered through a pad of celite and concentrated. The residue was purified by column chromatography (silica gel, ethyl acetate-hexanes; 9:1) to afford diethyl 2-[3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propyl-benzyl)phenyl]ethylphosphonate (450 mg, 93.5%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.99 (s, 1H), 6.98 (s, 2H), 6.88 (m, 1H), 6.66 (m, 1H), 4.65 (m, 4H), 3.99 (s, 2H), 3.19 (m, 1H), 2.88 (m, 2H), 2.24 (s, 6H), 2.10 (m, 2H), 1.51 (m, 6H), 1.25 (d, J = 6.9 Hz, 6H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:1); R_f = 0.53.

Step c:

Diethyl 2-[3,5-dimethyl-4-(4'-fluoro-3'-*iso*-propyl-benzyl)phenyl]ethylphosphonate was transformed into the title compound by the procedure described for the synthesis of compound 35, step h to give a white solid (60 mg, 35%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.09 (m, 1H), 6.98 (m, 1H), 6.92 (s, 2H), 6.66 (m, 1H), 3.94 (s, 2H), 3.95 (s, 2H), 3.11 (m, 1H), 2.70 (m, 2H), 2.18 (s, 6H), 1.80 (m, 2H), 1.19 (d, J = 7.2 Hz, 6H). mp = 116~118, LC-MS m/z = 365 $[C_{20}H_{26}FO_3P + H]^+$; Anal. Calcd for ($C_{20}H_{26}FO_3P$): C, 65.92; H, 7.19. Found: C, 65.68; H, 7.19.

<u>Example 43</u>

<u>**Compound 43:** [3,5-dimethyl-4-S-[(4'-hydroxy-3'-*iso*-propylphenyl)sulfanyl]phenoxy]methylphosphonate:</u>

Step a:

A mixture of 3,5-Dimethyl-4-iodophenol (2.0 g, 8.06mmol), potassium carbonate (3.33 g, 24.2 mmol) and methyl iodine (602 µl, 9.67 mmol) in DMF (20 mL) under a nitrogen atmosphere was heated at 65 C, with stirring for 16 hours. The cooled reaction was diluted with ethyl acetate (50 mL), filtered into a sep-funnel and washed with water (2x 25mL) then brine (25 mL). The organics were dried over sodium sulfate, filtered and the solvent removed under reduced pressure to give (1.68 g, 79%); ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.79(s, 2H), 3.72(s, 3H), 2.37(s, 6H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 5% ethyl acetate in hexane; R_f = 0.47.

Step b:

Copper iodine (70 mg, 0.37 mmol), neocuprinine (80 mg, 0.37 mmol) and potassium *t*-butoxide (470 mg, 4.05 mmol) were added in this order to a solution of 4-methoxy-3-*iso*-propyl-thiophenol (U.S 6,747,048 B2, 600mg, 2.3 mmol) and 3,5-dimethyl-4-iodoanisole (678 mg, 3.72 mmol) in toluene (10mL). After refluxing overnight, the cooled reaction mixture was poured into ethyl acetate (50 mL) and washed twice with 1 N HCl then brine. The organics were dried over sodium sulfate, filtered and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, hexane/ethyl acetate 100:0 to 40:1) to give 3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxyphenylsulfanyl)anisole (0.358 g, 49%); ^{1}H NMR (200 MHz, DMSO-d_6): δ 6.87-6.80(m, 4H), 6.56(m, 1H), 3.76(s, 3H), 3.71(s, 3H), 3.15(m, 1H), 2.34(s, 6H), 1.06(d, 6H, J = 7Hz); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 25% ethyl acetate in hexane; R_f = 0.36

Step c:

3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propyl-phenylsulfanyl)phenol was prepared from 2,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxy-phenylsulfanyl)anisole according to the procedure described in example 8, step d. ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.58(bs, 1H), 9.21(bs, 1H), 6.77(m, 1H), 6.63(m, 3H), 6.46(dd, 1H, J = 2.7 Hz and J = 8.1 Hz), 3.09(m, 1H), 2.28(s, 6H), 1.06(d, 6H, J = 7.2 Hz); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate 25% in hexane; R_f = 0.12

Step d:

diethyl [3,5-Dimethyl-4-(4'-hydroxy-3'-*iso*-propyl-phenylsulfanyl)-phenoxy]methyl phosphonate was prepared according to the procedure described in compound 8, step e: ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.26(s, 1H), 6.92(s, 2H), 6.81(d, 1H, J = 2.4 Hz), 6.65(d, 1H, J = 8.4 Hz), 6.47(dd, 1H, J = 2.1 Hz and J = 8 Hz), 4.42(d, 2H, J = 10 Hz), 4.11(m, 4H), 3.10(m, 1H), 2.35(s, 6H), 1.25(m, 6H), 1.06(d, 6H, J = 2.9 Hz); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate 50% in hexane; R_f = 0.12

Step f:

The title compound was prepared according to the procedure described in compound 8, step f: ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.22 (s, 1H), 6.88 (s, 2H), 6.81 (d, J = 2.1 Hz, 1H), 6.64 (d, J = 8.4 Hz, 1H), 6.46 (dd, J = 2 Hz and J = 8.2 Hz, 1H), 4.08 (d, J = 10.2 Hz, 2H), 3.10 (m, 1H), 2.34 (s, 6H), 1.07 (d, J = 6.6 H, 6H z); LC-MS m/z =

381 [$C_{18}H_{23}O_5PS$- H]$^-$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = IPA/NH_4OH/H_2O [7:1:2]; R_f = 0.53; HPLC, YMC Pack ODS-AQ, AQ 302, 150mm x 4.6 mm, S 5 µm, 12nm, flow 2 mL/min, solvent A: 0.05% TFA aqueous, Solvent B: acetonitrile/0.05%TFA, Gradient 20% B to 70% B in 13min – hold 1 min at 70%B – gradient to 100%B in 6 min. Rt=10.23 min.

Example 44:

Compound 44: [3,5-dimethyl-4-[4'-hydroxy-3'-(*iso*-propylsulfonyl)benzyl]phenoxy]methylphosphonic acid

Step a:

Triisopropyl-[3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylsulfanylbenzyl)-phenoxy]silane was synthesized according to the procedure described in example 35, step d using di-*iso*-propyl disulfide as the electrophile. The product of this reaction was carried in the next step as a mixture of desired product and starting material triisopropyl-[3,5-dimethyl-4-(4'-methoxymethoxybenzyl)-phenoxy]silane: ^{1}H NMR (200 MHz, DMSO-d_6): δ 1.15 (d, J = 6.4 Hz, 6H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 5% ethyl acetate in hexane; R_f = 0.32

Step b:

3,5-Dimethyl 4-(4'-methoxymethoxy-3'-*iso*-propylsulfanylbenzyl)phenol was prepared according to the procedure described in example 35, step e. The product of this reaction was carried on as a mixture of desired product and 3,5-dimethyl 4-(4'-methoxymethoxybenzyl)phenol: ^{1}H NMR (200 MHz, DMSO-d_6): δ 1.16 (d, J = 9.9 Hz, 6H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 5% ethyl acetate in hexane; R_f = 0.25

Step c:

Diethyl [3,5-dimethyl 4-(4'-methoxymethoxy-3'-*iso*-propylsulfanylbenzyl)phenoxy]methylphosphonate was prepared according to the procedure described in example 8, step e and carried on as a mixture of desired product and diethyl [3,5-dimethyl 4-(4'-methoxymethoxybenzyl)phenoxy]methylphosphonate: ^{1}H NMR (200 MHz, DMSO-d_6): δ 4.36 (d, 2H, J = 15Hz), 4.11 (m, 4H), 1.26 (t, 6H, J = 10.8 Hz), 1.16 (d, 6H, J = 9.9 Hz); LC-MS m/z = 465 [$C_{23}H_{36}O_6PS$+ H]$^+$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 50% ethyl acetate in hexane; R_f = 0.12

Step d:

A mixture diethyl [3,5-dimethyl 4-(4'-methoxymethoxy-3'-*iso*-propylsulfanylbenzyl)phenoxy]methylphosphonate (0.200g, 0.402mmol), saturated sodium bicarbonate (1 Ml) and *m*CPBA 50%-60% (0.173 g, 1.01 mmol) in dichloromethane (5 mL) was stirred overnight at room temperature. The layers were separated and the organics were dried over sodium sulfate, filtered and concentrated under reduced pressure. The residue was purified by preparative TLC (2000 µm, 5% hexanes in ethyl acetate) to give diethyl [3,5-dimethyl-4-[4'-methoxymethoxy-3'-(*iso*-propyl sulfonyl)benzyl]phenoxy]methylphosphonate (0.090 g, 42%); ^{1}H NMR (200 MHz, DMSO-d_6): δ 7.42 (s, 1H), 7.24 (s, 2H), 6.77 (s, 2H), 5.32 (s, 2H), 4.36 (d, J = 10 Hz, 2H), 4.11 (m, 4H), 3.96 (s, 2H), 3.69 (m, 1H), 3.39 (s, 3H), 2.16 (s, 6H), 1.26 (t, J = 7 Hz, 6H), 1.12 (d, J = 7 Hz, 6H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate; R_f = 0.28

Step e:

The title compound was prepared according to the described for example 8, step f (0.057 g, 82); ^{1}H NMR (200 MHz, DMSO-d_6): δ 10.89 (bs, 1H), 7.31 (s, 1H), 7.12 (dd, J = 5.8, 2.2 Hz, 1H z), 6.93 (d, J = 8 H, 1H z), 6.72 (s, 2H), 4.04 (d, J = 10.2 H, 2H z), 3.89 (s, 2H), 3.64 (m, 1H), 2.15 (s, 6H), 1.11 (d, J = 7 Hz, 6H); LC-MS m/z = 427 $[C_{19}H_{25}O_7PS\text{- }H]^-$; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = *iso*-propyl alcohol/NH_4OH/H_2O [7:1:2]; R_f = 0.53; Anal. Calcd for ($C_{18}H_{23}O_5PS$ + 1 M H_2O + 0.1 M EtOAc) C, 51.18; H, 6.15 . Found: C, 51.01; H, 5.94.

Example 45

Compound 45: [4,6-Dimethyl-5-(4'-hydroxy-3'-*iso*-propyl)benzyl]benzofuran-2-phosphonic Acid

Step a:

To a mixture of 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol (1.0 g, 3.18 mmol, G. Chiellini *et al. Bioorg. Med. Chem. Lett.* **2000**, *10*, 2607) in C_2H_5OH (30.0 mL) and 40% aqueous methylamine (6.20 mL) at 0 °C was added a solution of potassium iodide (2.5 g, 15.0 mmol) and iodine (0.98 g, 3.82 mmol) in H_2O (6.20 mL). The reaction mixture was stirred at 0 °C for 1 h, quenched with water and extracted with ethyl acetate (2x30 mL). The organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with 20% ethyl acetate in hexanes to afford

3,5-dimethyl-2-iodo-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol as white solid: ^{1}H NMR (300 MHz, CD_3OD): δ 6.93 (m, 2 H), 6.65 (m, 2 H), 5.18 (s, 2 H), 4.05 (s, 2 H), 3.48 (s, 3 H), 3.30 (m, 1 H), 2.41 (s, 3 H), 2.19 (s, 3 H), 1.18 (d, J = 6.6 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:5); R_f = 0.60.

Step b:

To a mixture of Cu_2O (0.08 g, 0.57 mmol) in DMF (2.0 mL) was added a solution of diethyl ethynylphosphonate (0.11g, 0.68 mmol) in DMF (0.5 mL) followed by a solution of 3,5-dimethyl-2-iodo-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol in diisopropylethylamine (0.40 mL) and DMF (1.0 mL). The reaction mixture was heated at 90 °C for 48 h, cooled to room temperature and filtered through a Celite plug. The solution was diluted with water (30 mL) and extracted with ethyl acetate (30 mL). The organic layer was separated, dried over $MgSO_4$. The solvent was removed under reduced pressure and the crude product was purified by column chromatography on silica gel, eluting with 50% ethyl acetate in hexanes to afford diethyl [4,6-Dimethyl-5-(4'-hydroxy-3'-*iso*-propyl)benzyl]benzofuran-2-phosphonate (0.07 g, 26%) as colorless oil: ^{1}H NMR (300 MHz, CD_3OD): δ 7.66 (dd, J = 8.1, 2.4 Hz, 1 H), 7.35 (s, 1 H), 6.97 (d, J = 2.1 Hz, 1 H), 6.92 (d, J = 8.1 Hz, 1 H), 6.64 (dd, J = 8.1, 2.1 Hz, 1 H), 5.18 (s, 2 H), 4.24 (m, 4 H), 4.14 (s, 2 H), 3.47 (s, 3 H), 3.30 (m, 1 H), 2.49 (s, 3 H), 2.39 (s, 3 H), 1.40 (t, , J = 6.0 Hz, 6 H), 1.14 (d, J = 6.6 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:1); R_f = 0.50.

Step c:

[4,6-Dimethyl-5-(4'-hydroxy-3'-*iso*-propyl)benzyl]benzofuran-2-phosphonic acid was prepared from diethyl [4,6-Dimethyl-5-(4'-hydroxy-3'-*iso*-propyl)benzyl]benzofuran-2-phosphonate according to the procedure described in example 7, step b: mp: 180-182 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 7.44 (dd, J = 8.1, 2.4 Hz, 1 H), 7.30 (s, 1 H), 6.85 (d, J = 2.1 Hz, 1 H), 6.61 (d, J = 8.1 Hz, 1 H), 6.55 (d, J = 8.1 Hz, 1 H), 4.08 (s, 2 H), 3.24 (m, 1 H), 2.46 (s, 3 H), 2.37 (s, 3 H), 1.14 (d, J = 6.6 Hz, 6 H); LC-MS m/z = 375 $[C_{20}H_{23}O_5P + H]^+$; Anal. Calcd for ($C_{20}H_{23}O_5P$+0.7 H_2O+0.1 CH_3OH): C, 61.87; H, 6.41. Found: C, 61.80; H, 6.60.

Example 46

Compound 46: [3,5-Dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)-2-iodophenoxy]methylphosphonic Acid

The title compound was prepared from 3,5- dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxy)benzyl-2-iodophenol (compound 45,stepa) according to the procedure described in example 7: ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.00 (s, 1 H), 6.87 (d, J = 3.9 Hz, 1 H), 6.61 (d, J = 12.0 Hz, 1 H), 6.40 (d, J = 12.6 Hz, 1 H), 4.32 (d, J = 10.2 Hz, 2 H), 3.94 (s, 2 H), 3.12 (m, 1 H), 2.36 (s, 3 H), 2.21 (s, 3 H); LC-MS m/z = 491 $[C_{19}H_{24}IO_5P + H]^+$; Anal Calcd for $C_{19}H_{24}IO_5P$: C, 46.55; H, 4.93. Found: C, 46.93; H, 4.99.

Example 47

Compound 47: [3,5-Dimethyl 4-(4'-hydroxy-3'-*iso*-propylbenzyl)-phenylamino]methylphosphonic Acid

Step a:

A solution of 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)-trifluoromethanesulfonyloxyphenyl (2.04 g, 4.57 mmol, intermediate for the synthesis of compound 24-1), triethylamine (1.27 mL, 9.14 mmol), 1,3-bis(diphenylphosphino)propane (0.19 mL, 0.45 mmol), MeOH (3.71 mL, 91.40 mmol), and $Pd(OAc)_2$ (0.102 g, 0.46 mmol) in DMF (25 mL) was heated at 90 °C under 60 psi of CO in a Parr reactor for 16 h. The reaction mixture was cooled to 0 °C, diluted with ethyl acetate (25 mL) and washed with H_2O (25 mLx2). The organic solution was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:4) to afford methyl 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)benzoate as an oil (1.52 g, 93%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.68 (s, 2 H), 6.97 (m, 1 H), 6.91 (m, 2 H), 6.20 (m, 1 H), 5.16 (s, 2 H), 4.01 (s, 3 H), 3.85 (s, 3 H), 3.21 (m, 1 H), 2.28 (s, 6 H), 1.14 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:4); R_f = 0.42.

Step b:

To a stirring solution of methyl 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)benzoate (0.750 g, 2.11 mmol) in MeOH (20.0 mL) at 0 °C was added 1 M NaOH (12.64 mL, 12.64 mmol). The reaction mixture was heated at 50 °C for 16 h,

cooled to 0 °C and acidified with 2 N HCl. The mixture was extracted with ethyl acetate (20 mL) and washed with H_2O (10 mLx2.). The solvent was removed under reduced pressure to afford 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)benzoic acid as white solid (0.71 g, 98%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 12.76 (s, 1 H), 7.65 (s, 2 H), 6.98 (m, 1 H), 6.91 (m, 1 H), 6.60 (m, 1 H), 5.17 (s, 2H), 4.00 (s, 2 H), 3.37 (s, 3 H), 3.23 (m, 1 H), 2.27 (s, 6 H), 1.14 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (4:1); R_f = 0.00.

Step c:

To a suspension of 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)benzoic acid (0.70 g, 2.04 mmol), *tert*-butanol (0.756 mg, 10.22 mmol) and triethylamine (0.71 g, 5.11 mmol) in toluene (30 mL) was added diphenylphosphoryl azide (0.44 mL, 2.04 mmol). The reaction mixture was heated under reflux for 16 h, cooled to room temperature and poured into a cold solution of 0.25 M HCl (30 mL). The mixture was diluted with ethyl acetate and washed with H_2O (30 mL). The organic layer was separated and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:9) to afford *t*-butyl *N*-3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)carbamate as a yellow oil (0.63 g, 75%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.16 (s, 1 H), 7.16 (s, 2 H), 6.96 (m, 1 H), 6.90 (m, 1 H), 6.62 (m, 1 H), 5.16 (s, 2 H), 3.86 (s, 2 H), 3.37 (s, 3 H), 3.22 (m, 1 H), 2.15 (s, 6 H), 1.48 (m, 9 H), 1.23 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (3:7); R_f = 0.72.

Step d:

To a mixture of *t*-butyl *N*-3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)carbamate (0.315 g, 0.76 mmol) in THF (8.0 mL) at -78 °C was added lithium diisopropylamide (0.46 g, 0. 91 mmol, 2.0 M solution in THF/heptane/ethylbenzene). The reaction mixture was stirred at -78 °C for 20 min and trifluoromethanesulfonic acid diethoxyphosphorylmethyl ester (0.16 g, 0.76 mmol) was added. The reaction mixture was stirred at -78 °C for 1 h, allowed to warm to room temperature and stirred for 4 h. The reaction mixture was quenched with 2.5 M aqueous ammonium chloride and diluted with ethyl acetate. The organic layer was washed with saturated aqueous ammonium chloride (8.0 mL), H_2O (8.0 mL) and brine (8.0 mL). The organic solution was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl *N*-*t*-butoxycarbonyl-[3,5-

dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenylamino]methylphosphonate as an oil (0.21 g, 49%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.00 (s, 2 H), 6.94 (m, 1 H), 6.90 (m, 1 H), 6.64 (m, 1 H), 5.16 (s, 2 H), 4.09 (d, J = 6.0 Hz, 2 H), 4.00 (m, 4 H), 3.8 (m, 2 H), 3.37 (s, 3 H), 3.22 (m, 1 H), 2.20 (s, 6 H), 1.40 (s, 9 H), 1.27 (m, 6 H), 1.13 (m, 6 H); ; TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (3:2); R_f = 0.20

Step e:

To a stirring solution of diethyl *N*-*t*-butoxycarbonyl-[3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenylamino]methylphosphonate (0.19 g, 0.34 mmol) in MeOH (4.0 mL) at 0 °C was added 2 M HCl (1.68 mL, 3.37 mmol). The reaction mixture was allowed to warm to room temperature and stirred for 48 h. The reaction mixture was cooled to 0 °C, neutralized with $NaHCO_3$, diluted with ethyl acetate (20 mL) and washed with H_2O (10 mLx2). The organic solution was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (3:2) to afford diethyl [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenylamino]methylphosphonate as a white solid (0.07 g, 51%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.95 (s, 1 H), 6.84 (m, 1 H), 6.63 (m, 1 H), 6.50 (m, 1 H), 6.45 (s, 2 H), 5.39 (m, 1H), 4.06 (s, 6 H), 3.74 (s, 2 H), 3.51 (m, 2 H), 3.13 (m, 1 H), 2.09 (s, 6 H), 1.20 (m, 6 H), 1.11 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (4:1); R_f = 0.29.

Step f:

To a solution of diethyl [3,5-dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenylamino]methylphosphonate (0.070 g, 0.17 mmol) in CH_2Cl_2 (3.0 mL) at -30 °C was added bromotrimethylsilane (0.28 mL, 2.08 mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was treated with acetonitrile-water (4:1, 5.0 mL) and stirred at 38 °C for 30 min. The solvent was removed under reduced pressure. The residue was dissolved in ethyl acetate and washed with H_2O. The organic solution was dried over $MgSO_4$, filtered and concentrated under reduced pressure to afford the title compound as an off-white powder (0.050 g, 79%); mp: 147-150 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.97 (s, 1 H), 6.86 (m, 1 H), 6.59 (m, 1 H), 6.49 (m, 1 H), 6.45 (s, 2 H), 3.74 (s, 2 H), 3.20 (d, J = 12.0 Hz, 2 H), 3.13 (m, 1 H), 2.10 (s, 6 H), 1.12 (d, J = 6.0 Hz, 6 H); LC-MS m/z = 364 $[C_{19}H_{26}NO_4P - H]^+$; Anal. Calcd for ($C_{19}H_{26}NO_4P$ + 1.0 H_2O +

0.2 HBr + 0.2 $CH_3CO_2CH_2CH_3$): C, 57.28; H, 7.23; N, 3.37; Br, 3.85. Found: C, 57.60; H, 7.33; N, 3.12; Br, 3.48.

Example 48

Compound 48: [4-(3'-cyclopropyl-4'-hydroxybenzyl)-3,5-dimethylphenoxy]methylphosphonic acid

Step a:

To a suspension of methyltriphosphonium bromide (4.81 g, 13.46 mmol) in THF (10.0 mL) at 0 °C was added n-butyllithium (4.30 g, 10.76 mmol, 2.5 M solution in hexane). The reaction mixture was stirred at 0 °C for 1 h and to it was added a solution of 5-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-2-methoxymethoxy-benzaldehyde (1.23 g, 2.69 mmol, intermediate for the synthesis of Example 35, step d) in THF (5.0 mL). The reaction mixture was stirred at room temperature for 2.5 h, cooled to 0 °C and quenched with saturated ammonium chloride (15.0 mL). The mixture was extracted with ethyl acetate (20 mL), washed with H_2O (25 mLx2) and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:50) to afford triisopropyl-[3,5-dimethyl-4-(4'-methoxymethoxy-3'-vinylbenzyl)phenoxy]silane as oil (1.19 g, 97%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.12 (m, 1 H), 7.00-6.93 (m, 2 H), 6.80 (m, 1 H), 6.59 (s, 2 H), 5.62 (d, J = 18.0 Hz, 1 H), 5.24 (d, J = 12.0 Hz, 1 H), 5.19 (s, 2 H), 3.88 (s, 2 H), 3.37 (s, 3 H), 2.15 (s, 6 H), 1.37 (s, 1 H), 1.21 (m, 3 H), 1.08 (d, J = 4.5 Hz, 18 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:5); R_f = 0.74.

Step b:

A mixture of copper powder (0.094 g, 1.48 mmol) and iodine (0.005 g, 0.016 mmol) in benzene (2.3 mL) was stirred at room temperature for 10 min. To it was added a solution of triisopropyl-[3,5-dimethyl-4-(4'-methoxymethoxy-3'-vinylbenzyl)phenoxy]silane (0.15 g, 0.33 mmol) in benzene (1.0 mL) followed by diiodomethane (0.053mL, 0.66 mmol). The reaction mixture was heated at 70 °C for 144 h, cooled to room temperature and filtered through a Celite plug. The solvent was removed under reduced pressure to afford triisopropy-[4-(3'-cyclopropyl-4'-methoxymethoxybenzyl)-3,5-dimethylphenoxy]silane as oil (0.14 g, 91%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.92 (m, 1 H), 6.67 (m, 1 H), 6.58 (s, 2 H), 6.43 (s, 1 H), 5.18 (s, 2 H), 3.82 (s, 2 H), 3.39 (s, 3 H), 2.14 (s, 6 H), 1.26 (m, 3 H), 1.08 (d, J = 4.5 Hz, 18

H), 0.87 (m, 2 H), 0.46 (m, 2 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:5); $R_f = 0.74$.

Step c:

To a mixture of triisopropy-[3,5-dimethyl-4-(3'-cyclopropyl-4'-methoxymethoxybenzyl)phenoxy]silane (0.38 g, 0.81 mmol) in THF (10.0 mL) at 0 °C was added TBAF (1.22 mL, 0.81 mmol, 1.0 M in THF). The reaction mixture was stirred at room temperature for 1 h, diluted with diethyl ether (20 mL) and washed with H_2O (20 mLx2). The organic solution was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:9) to afford 4-(3'-cyclopropyl-4'-methoxymethoxybenzyl)-3,5-dimethylphenol as an oil (0.18 g, 71%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.01 (s, 1 H), 6.90 (m, 1 H), 6.61 (m, 1 H), 6.58 (s, 1 H), 6.46 (s, 2 H), 5.17 (s, 2 H), 3.77 (s, 2 H), 3.39 (s, 3 H), 2.11 (s, 6 H), 0.87 (m, 2 H), 0.51 (m, 2 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:9); $R_f = 0.47$.

Step d:

To a mixture of 4-(3'-cyclopropyl-4'-methoxymethoxybenzyl)-3,5-dimethylphenol (0.16 g, 0.53 mmol) and Cs_2CO_3 (0.859 g, 2.64 mmol) in DMF (6.0 mL) at 0 °C was added trifluoromethanesulfonic acid diethoxyphosphorylmethyl ester (0.11 g, 0.53 mmol). The reaction mixture was stirred at 0 °C for 5 h, allowed to warm to room temperature and stirred for 16 h. The reaction mixture was cooled to 0 °C, quenched with cold 1 N HCl and extracted with ethyl acetate (8.0 mL). The organic solution was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl [4-(3'-cyclopropyl-4'-methoxymethoxybenzyl)-3,5-dimethylphenoxy]methylphosphonate as oil (0.10 g, 28%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.90 (m, 1 H), 6.75 (s, 2 H), 6.59 (m, 2 H), 5.17 (s, 2 H), 4.39 (d, J = 9.0 Hz, 2 H), 4.15 (m, 4 H), 3.83 (s, 2 H), 3.39 (s, 3 H), 2.19 (s, 6 H), 2.09 (m, 1 H), 1.24 (m, 6 H), 0.87 (m, 2 H), 0.52 (m, 2 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (4:1); $R_f = 0.25$

Step e:

To a solution of diethyl [4-(3'-cyclopropyl-4'-methoxymethoxybenzyl)-3,5-dimethylphenoxy]methylphosphonate (0.090 g, 0.19 mmol) in CH_2Cl_2 (3.0 mL) at -30 °C was added bromotrimethylsilane (0.26 mL, 1.94 mmol). The reaction mixture was

stirred at room temperature 16 h and the solvent was removed under reduced pressure. The residue was treated with acetonitrile-water (4:1, 5.0 mL), stirred at 38 °C for 30 min and concentrated under reduced pressure. The residue was dissolved in ethyl acetate and washed with H_2O. The organic solution was dried over $MgSO_4$, filtered and concentrated under reduced pressure to afford the title compound as an off-white powder (0.040 g, 57%); mp: 153-156 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.02 (s, 1 H), 6.67 (s, 2 H), 6.58 (m, 1 H), 6.41 (m, 2 H), 4.00 (d, J = 10.5 Hz, 2 H), 3.75 (s, 2 H), 2.13 (s, 6 H), 1.98 (m, 1 H), 0.81 (m, 2 H), 0.47 (m, 2 H); LC-MS m/z = 362 [$C_{19}H_{23}O_5P$ - H]$^+$; Anal. Calcd for ($C_{19}H_{23}O_5P$ + 0.9 H_2O): C, 60.28; H, 6.60. Found: C, 60.40; H, 6.92.

Example 49

Compound 49: [4-(3'-Dimethylamino-4'-hydroxybenzyl)-3,5-dimethylphenoxy]methylphosphonic acid

Step a:

To a stirring solution of 4-bromo-2-nitro-phenol (6 g, 27.52 mmol) in MeOH (150 mL) at room temperature was added a suspension of $Na_2S_2O_4$ (29 g, 165.13 mmol). The mixture was stirred at room temperature for 3 hrs, filtered and concentrated down. The residue was partitioned between EtOAc and water. The organic layer was collected and dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford crude 2-amino-4-bromo-phenol as a yellow solid (3.9 g, 75%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.27 (s, 1 H), 6.70 (d, J = 2.2 Hz, 1 H), 6.50 (m, 2 H), 4.79 (s, 2 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 20% ethyl acetate in hexanes; R_f = 0.35.

Step b:

2-Amino-4-bromo-phenol (3.9 g, 20.74 mmol) was dissolved into AcOH (120 mL) and heated to 40 °C. To this stirring solution at 40 °C was added (HCHO)n (1.9 g, 62.23 mmol), followed by $NaBH_3CN$ (3.9 g, 62.23 mmol). The reaction mixture was stirred for 1 hr at 40 °C, then another (HCHO)n (1.9 g, 62.23 mmol) and $NaBH_3CN$ (3.9 g, 62.23 mmol) were added. The mixture was stirred for 16 hrs at 40 °C. The solvent was removed under reduced pressure. The residues were partitioned between EtOAc and water. The organic layer was collected and dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (30:70) to afford 4-bromo-2-dimethylamino-phenol as a light yellow solid (3.7 g, 83%): ^{1}H NMR (300 MHz, DMSO-

d_6): δ 9.44 (s, 1 H), 6.92 (m, 2 H), 6.71 (d, J = 8.4 Hz, 1 H), 2.69 (s, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 20% ethyl acetate in hexanes; R_f = 0.57.

Step c:

Toa stirring solution of 4-bromo-2-dimethylamino-phenol (3.7 g, 17.13 mmol) in CH_2Cl_2 (100 mL) at room temperature was added ethyl-diisopropyl-amine (4.47 mL, 25.7 mmol) and chloro-methoxy-methane (1.69 mL, 22.27 mmol). The mixture was refluxed for 16 hrs, added water. The organic layer was collected and dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford crude *N*-(5-bromo-2-methoxymethoxyphenyl)dimethylamine as a red oil (4.4 g, 99%): ^{1}H NMR (200 MHz, DMSO-d_6): 6.96 (m, 3 H), 5.17 (s, 2 H), 3.40 (s, 3 H), 2.72 (s, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 15% ethyl acetate in hexanes; R_f = 0.59.

Step d:

To a stirring solution of *N*-(5-bromo-2-methoxymethoxy-phenyl)dimethylamine (3.4 g, 13.07 mmol) in THF (80 mL) at –78 °C was added *n*-BuLi (5.22 mL, 2.5 M in hexanes). The mixture was stirred at –78 °C for 1 hr and a solution of 2,6-dimethyl-4-triisopropylsilanyloxy-benzaldehyde (3.6 g, 11.77 mmol) was added. The reaction mixture was stirred at –78 °C for 1 hr, allowed to warm to room temperature and stirred for 1 hr. The reaction mixture was quenched with saturated NH_4Cl and diluted with diethyl ether. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (30:70) to afford (3-dimethylamino-4-methoxymethoxy-phenyl)-(2,6-dimethyl-4-triisopropylsilanyloxyphenyl)methanol as a yellow oil (4 g, 63%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.89 (d, J = 8.4 Hz, 1 H), 6.79 (s, 1 H), 6.61 (m, 1 H), 6.51 (s, 2 H), 6.01 (d, J = 4.0 Hz, 1 H), 5.65 (d, J = 4.0 Hz, 1 H), 5.14 (s, 2 H), 3.41 (s, 3 H), 2.64 (s, 6 H), 2.17 (s, 6 H), 1.24 (m, 3 H), 1.08 (d, J = 7.2 Hz, 18 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 25% ethyl acetate in hexanes; R_f = 0.27.

Step e:

To a stirring solution of (3-dimethylamino-4-methoxymethoxy-phenyl)-(2,6-dimethyl-4-triisopropylsilanyloxy-phenyl)-methanol (3.4 g, 6.97 mmol) in CH_2Cl_2 (150 mL) at room temperature was added Et_3SiH (5.6 mL, 34.85 mmol) and TFA (2.6 mL,

34.85 mmol). The reaction mixture was stirred at room temperature for 6 hrs. The solvent was removed under reduced pressure and the residue was partitioned between ethyl acetate and saturated $NaHCO_3$. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (3:7) to afford *N*-[5-(2',6'-dimethyl-4'-triisopropylsilanyloxybenzyl)-2-methoxymethoxyphenyl]dimethylamine as a yellow oil (3 g, 91%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.86 (d, J = 8.1 Hz, 1 H), 6.59 (s, 2 H), 6.54 (d, J = 2.1 Hz, 1 H), 6.41 (m, 1 H), 5.12 (s, 2 H), 3.85 (s, 2 H), 3.40 (s, 3 H), 2.64 (s, 6 H), 2.15 (s, 6 H), 1.26 (m, 3 H), 1.08 (d, J = 7.2 Hz, 18 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (25:75); R_f = 0.54.

Step f:

To a stirring solution of *N*-[5-(2',6'-dimethyl-4'-triisopropylsilanyloxybenzyl)-2-methoxymethoxyphenyl]dimethylamine (3 g, 6.36 mmol) in THF (60 mL) at room temperature was added tetrabutylammonium fluoride (9.54 mL, 1.0 M in THF). The reaction mixture was stirred at room temperature for 2 hr, diluted with diethyl ether and washed with water (30 mLx2). The solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford 4-(3'-dimethylamino-4'-methoxymethoxybenzyl)-3,5-dimethylphenol as a light yellow oil (1.8 g, 90%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.01 (s, 1 H), δ 6.85 (d, J = 8.1 Hz, 1 H), 6.63 (d, J = 2.1 Hz, 1 H), 6.47 (s, 2 H), 6.35 (m, 1 H), 5.12 (s, 2 H), 3.80 (s, 2 H), 3.40 (s, 3 H), 2.67 (s, 6 H), 2.17 (s, 6 H), TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 30% ethyl acetate in hexanes; R_f = 0.28.

Step g:

To a stirring solution of 4-(3'-dimethylamino-4'-methoxymethoxybenzyl)-3,5-dimethylphenol (0.525 g, 1.66 mmol) in DMF (18 mL) at 0 °C was added NaH (80 mg, 1.99 mmol, 60%) and stirred for 1 hr at room temperature. Diethyl tosyloxymethylphosphonate (0.7 g, 2.16 mmol) was added and the mixture was stirred for 16 hrs at room temperature. The solvent was removed under reduced pressure, and the residue was partitioned between EtOAc and sat. $NaHCO_3$. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes

(8:2) to afford diethyl [4-(3'-dimethylamino-4'-methoxymethoxybenzyl)-3,5-dimethylphenoxy]methylphosphonate as a light yellow oil (0.5 g, 65%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.85 (d, J = 8.1 Hz, 1 H), 6.76 (s, 2 H), 6.64 (d, J = 2.1 Hz, 1 H), 6.34 (m, 1 H), 5.12 (s, 2 H), 4.38 (d, J = 9.8 Hz, 2 H), 4.14 (m, 4 H), 3.86 (s, 2 H), 3.40 (s, 3 H), 2.67 (s, 6 H), 2.19 (s, 6 H), 1.25 (t, J = 7.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (6:4); R_f = 0.43.

Step h:

To a stirring solution of diethyl [4-(3'-dimethylamino-4'-methoxymethoxybenzyl)-3,5-dimethylphenoxy]methylphosphonate (0.48 g, 1.03 mmol) in MeOH (6 mL) and water (1 mL) at room temperature was added HCl (1.03 mL, 10 N), and heated at 100 °C for 5 min by microwave. The solvent was removed under reduced pressure, and the residue was partitioned between EtOAc and sat. $NaHCO_3$. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate- CH_2Cl_2 (3:1) to afford diethyl [4-(3'-dimethylamino-4'-hydroxybenzyl)-3,5-dimethyl-phenoxy]methylphosphonate as a light yellow oil (0.29 g, 67%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 8.77 (s, 1 H), δ 6.72 (s, 2 H), 6.57 (m, 2 H), 6.26 (m, 1 H), 4.35 (d, J = 9.8 Hz, 2 H), 4.13 (m, 4 H), 3.79 (s, 2 H), 2.60 (s, 6 H), 2.17 (s, 6 H), 1.25 (t, J = 7.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-CH_2Cl_2 (1:3); R_f = 0.49.

Step i:

The title compound was prepared according to the procedure described for the synthesis of compound 8, step f. ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.34 (s, 1 H), 6.92 (d, J = 8.7 Hz, 1 H), 6.79 (m, 1 H), 6.73 (s, 2 H), 4.03 (d, J = 10.2 Hz, 2 H), 3.88 (s, 2 H), 3.13 (s, 6 H), 2.17 (s, 6 H); mp: degasses at 90 °C; LC-MS m/z = 366 [C18H24NO5P + H]$^+$; Anal Calcd for (C18H24NO5P + 1.4HBr + 0.4H_2O + 0.1MeOH): C, 44.45; H, 5.48; N, 2.86; Br, 22.87. Found: C, 44.64; H, 5.67; N, 2.65; Br, 22.74.

Example 50

Compound 50: [4-(3'-Benzyloxycarbonylamino-4'-hydroxybenzyl)-3,5-dimethyl-phenoxy]methylphosphonic acid

Step a:

To a stirring solution of diethyl [3,5-dimethyl-4-(3'-carboxyl-4'-methoxymethoxybenzyl)phenoxy]methylphosphonate (0.36 g, 0.77 mmol) in toluene (20

mL) at room temperature was added diphenylphosphoryl azide (0.17 mL, 0.77 mmol), triethylamine (0.2 mL, 1.4 mmol) and benzyl alcohol (0.4 mL, 3.85 mmol). The mixture was refluxed for 16 hrs. The solvent was removed under reduced pressure, and the residue was partitioned between EtOAc and sat. NH_4Cl. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate to afford diethyl [4-(3'-benzyloxycarbonylamino-4'-methoxymethoxybenzyl)-3,5-dimethylphenoxy]methylphosphonate as a light yellow oil (0.4 g, 91%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.60 (s, 1 H), 7.38 (m, 6 H), 6.99 (d, J = 8.4 Hz, 1 H), 6.76 (s, 2 H), 6.65 (m, 1 H), 5.13 (s, 2 H), 5.12 (s, 2 H), 4.37 (d, J = 9.6 Hz, 2 H), 4.13 (m, 4 H), 3.87 (s, 2 H), 3.37 (s, 3 H), 2.19 (s, 6 H), 1.27 (t, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 75% ethyl acetate in hexanes; R_f = 0.45.

Step b:

To a stirring solution of diethyl [4-(3'-benzyloxycarbonylamino-4'-methoxymethoxy-benzyl)-3,5-dimethylphenoxy]methylphosphonic (0.1 g, 0.175 mmol) in MeOH (2 mL) at room temperature was added HCl (0.18 mL, 10 N), and the reaction mixture was heated at 100 °C for 5 min by microwave. The solvent was removed under reduced pressure, and the residue was partitioned between EtOAc and sat. $NaHCO_3$. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate to afford diethyl [4-(3'-benzyloxycarbonylamino-4'-hydroxybenzyl)-3,5-dimethylphenoxy]methylphosphonate as a light yellow oil (0.076 g, 82%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.48 (s, 1 H), 8.34 (s, 1 H), 7.38 (m, 6 H), 6.71 (m, 3 H), 6.53 (m, 1 H), 5.11 (s, 2 H), 4.37 (d, J = 9.6 Hz, 2 H), 4.13 (m, 4 H), 3.82 (s, 2 H), 2.19 (s, 6 H), 1.27 (t, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 75% ethyl acetate in hexanes; R_f = 0.40.

Step c:

To a stirring solution of diethyl [4-(3'-benzyloxycarbonylamino-4'-hydroxybenzyl)-3,5-dimethylphenoxy]methylphosphonic (0.076 g, 0.144 mmol) in CH_2Cl_2 (8 mL) at room temperature was added hexamethyldisilazane (0.28 mL, 1.27 mmol) and bromotrimethylsilane (0.15 mL, 1.15 mmol). The reaction mixture was stirred at room temperature for 16 hrs. The solvent was removed under reduced pressure, and the residue was partitioned between EtOAc and water. The organic layer was dried

over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was washed by CH_2Cl_2 to afford the title compound as a white amorphous solid (0.03 g, 44%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.41 (s, 1 H), 8.30 (s, 1 H), 7.33 (m, 6 H), 6.66 (m, 3 H), 6.48 (m, 1 H), 5.08 (s, 2 H), 3.97 (d, J = 10.2 Hz, 2 H), 3.77 (s, 2 H), 2.13 (s, 6 H). mp: shrink at 180 °C. LC-MS m/z = 472 [C24H26NO7P + H]$^+$; Anal Calcd for (C24H26NO7P+ 1.1H_2O): C, 58.68; H, 5.79; N, 2.85. Found: C, 58.44; H, 5.89; N, 2.77.

Example 51:

Compound 51-1: [3,5-dimethyl-4-(4'-Hydroxy-3'-methanesulfonylamino-benzyl)phenoxy]methylphosphonic acid

Step a:

To a solution of diethyl [4-(3'-benzyloxycarbonylamino-4'-methoxymethoxybenzyl)-3,5-dimethylphenoxy]methylphosphonic (0.33 g, 0.58 mmol) in EtOH (20 mL) at room temperature was added Pd/C (50 mg). The reaction mixture was stirred at room temperature under 50 psi H_2 for 16 hrs then filtered through Celite®. The solvent was removed under reduced pressure to afford diethyl [4-(3'-amino-4'-methoxymethoxybenzyl)-3,5-dimethylphenoxy]methylphosphonate as a colorless oil (0.25 g, 99%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.76 (m, 3 H), 6.29 (d, J = 2.4 Hz, 1 H), 6.12 (m, 1 H), 5.07 (s, 2 H), 4.69 (s, 2 H), 4.35 (d, J = 10.2 Hz, 2 H), 4.12 (m, 4 H), 3.76 (s, 2 H), 3.39 (s, 3 H), 2.19 (s, 6 H), 1.27 (t, J = 7 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 75% ethyl acetate in hexanes; R_f = 0.51.

Step b:

To a stirring solution of diethyl [4-(3'-amino-4'-methoxymethoxybenzyl)-3,5-dimethyl-phenoxy]methylphosphonic (0.13 g, 0.3 mmol) in CH_2Cl_2 (10 mL) at room temperature was added pyridine (0.037 mL, 0.45 mmol) and methanesulfonyl chloride (0.026 mL, 0.33 mmol). The reaction mixture was stirred at room temperature for 16 hrs. then partitioned between CH_2Cl_2 and water. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate to afford diethyl [3,5-dimethyl-4-(3'-methanesulfonylamino-4'-methoxymethoxybenzyl)phenoxy]methylphosphonate as a light yellow oil (0.12 g, 77%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.91 (s, 1 H), 7.02 (d, J = 8.4 Hz, 1 H), 6.96 (d, J = 2.1 Hz, 1 H), 6.76 (m, 3 H), 5.18 (s, 2 H), 4.37 (d, J = 9.9 Hz, 2 H), 4.16 (m, 4 H), 3.87

(s, 2 H), 3.41 (s, 3 H), 2.93 (s, 3 H), 2.19 (s, 6 H), 1.27 (t, $J = 6.9$ Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 75% ethyl acetate in hexanes; $R_f = 0.42$.

Step c:

To a stirring solution of diethyl [3,5-dimethyl-4-(3'-methanesulfonylamino-4'-methoxymethoxybenzyl)phenoxy]methylphosphonate (0.12 g, 0.23 mmol) in MeOH (2 mL) at room temperature was added HCl (1.2 mL, 2 N), and the reaction mixture was heated at 100 °C for 5 min by microwave. The solvent was removed under reduced pressure, and the residue was partitioned between EtOAc and sat. $NaHCO_3$. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate to afford diethyl [3,5-dimethyl-4-(4'-hydroxy-3'-methanesulfonylaminobenzyl) phenoxy]methylphosphonate as a white solid (0.08g, 74%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.85 (d, $J = 1.8$ Hz, 1 H), 6.76 (m, 3 H), 6.63 (m, 1 H), 4.37 (d, $J = 9.9$ Hz, 2 H), 4.14 (m, 4 H), 3.82 (s, 2 H), 2.89 (s, 3 H), 2.18 (s, 6 H), 1.27 (t, $J = 6.9$ Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate; $R_f = 0.42$.

Step d:

The title compound was prepared according to the procedure described in example 8, step f, (60 mg, 85%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.61 (s, 1 H), 8.61 (s, 1 H), 6.74 (m, 5 H), 4.02 (d, $J = 10.2$ Hz, 2 H), 3.80 (s, 2 H), 2.88 (s, 3 H), 2.16 (s, 6 H); mp: shrinks at 200 °C; LC-MS m/z = 416 [C17H22NO7PS + H]$^+$; Anal Calcd for (C17H22NO7PS + 0.1MeOH + 0.8H_2O): C, 47.43; H, 5.59; N, 3.23. Found: C, 47.57; H, 5.68; N, 3.10.

Using the appropriate starting materials, compounds 51-2 was prepared in an analogous manner to that described for the synthesis of compound 51-1

<u>Compound 51-2:</u> <u>[3,5-Dimethyl-4-(4'-hydroxy-3'-trifluoroacetylaminobenzyl)phenoxy]methylphosphonic acid</u>

^{1}H NMR (200 MHz, DMSO-d_6): δ 10.41 (s, 1 H), 9.71 (s, 1 H), 6.95 (s, 1 H), 6.74 (m, 4 H), 4.03 (d, $J = 10.2$ Hz, 2 H), 3.83 (s, 2 H), 2.16 (s, 6 H); mp: 170 - 172 °C; LC-MS m/z = 434 [C18H19F3NO6P + H]$^+$; Anal Calcd for (C18H19F3NO6P + 0.4H_2O): C, 49.08; H, 4.53; N, 3.18. Found: C, 49.26; H, 4.75; N, 2.83.

Compound 51-3: [3,5-dimethyl-4-(4'-Hydroxy-3'-isobutyrylaminobenzyl) phenoxy]methylphosphonic acid

Step a:

Diethyl (3'-amino-4'-hydroxybenzyl)-3,5-dimethylphenoxy]methylphosphonate was prepared according to the procedure described for the synthesis of example 51-1, step c: ^{1}H NMR (200 MHz, DMSO-d_6): δ 8.70 (s, 1 H), 6.71 (s, 2 H), 6.48 (d, J = 7.6 Hz, 1 H), 6.19 (s, 1 H), 6.01 (m, 1 H), 4.38 (s, 2 H), 4.33 (d, J = 9.6 Hz, 2 H), 4.12 (m, 4 H), 3.70 (s, 2 H), 2.16 (s, 6 H), 1.23 (t, J = 7.4 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 75% ethyl acetate in hexanes; R_f = 0.46.

Step b:

To a stirring solution of diethyl (3'-amino-4'-hydroxybenzyl)-3,5-dimethylphenoxy]methylphosphonate (0.046 g, 0.12 mmol) in THF (5 mL) at 0 °C was added pyridine (0.015 mL, 0.18 mmol) and isobutyric anhydride (0.021 mL, 0.13 mmol). The reaction mixture was stirred at 50 °C for 16 hrs. It was added EtOAc and water. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate to afford diethyl [3,5-dimethyl-4-(4'-hydroxy-3'-isobutyrylaminobenzyl) phenoxy]methylphosphonate as a yellow oil (0.046 g, 83%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.55 (s, 1 H), 9.22 (s, 1 H), 7.36 (s, 1 H), 6.73 (m, 3 H), 6.58 (m, 1 H), 4.36 (d, J = 9.6 Hz, 2 H), 4.13 (m, 4 H), 3.82 (s, 2 H), 2.73 (m, 1 H), 2.19 (s, 6 H), 1.27 (t, J = 6.9 Hz, 6 H), 1.07 (d, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 80% ethyl acetate in hexanes; R_f = 0.37.

Step c:

The title compound was prepared according to the procedure described for the synthesis of example 8, step f: ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.51 (s, 1 H), 9.22 (s, 1 H), 7.33 (s, 1 H), 6.72 (m, 3 H), 6.58 (m, 1 H), 4.03 (d, J = 10.2 Hz, 2 H), 3.80 (s, 2 H), 2.71 (m, 1 H), 2.17 (s, 6 H), 1.06 (d, J = 7.0 Hz, 6 H); LC-MS m/z = 408 [C20H26NO6P + H]$^+$; Anal Calcd for (C20H26NO6P + 0.9H_2O + 0.45HBr): C, 52.22; H, 6.19; N, 3.04; Br, 7.82. Found: C, 52.31; H, 6.42; N, 2.66; Br, 7.60.

Example 52:

Compound 52: [3,5-dimethyl-4-(4'-Hydroxy-3'-*iso*-propylbenzyl)benzenesulfonyl]methylphosphonic acid

Step a:

To a stirring solution of 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenylamine (0.5 g, 1.6 mmol) at 80 °C in dimethyldisulfide (5 mL) was added isoamylnitrite (0.86 mL, 6.4 mmol). The reaction mixture was stirred at 80 °C for 1 h. The solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:3) to afford 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)methylsulfanylbenzene as a light yellow oil (0.24 g, 44%): ^{1}H NMR (300 MHz, $CDCl_3$-d_1): δ 6.90 - 6.94 (m, 4 H), 6.62 (m, 1 H), 5.19 (s, 2 H), 3.97 (s, 2 H), 3.50 (s, 3 H), 3.31 (m, 1 H), 2.52 (s, 3 H), 2.25 (s, 6H) 1.20 (d, J = 6.9 Hz, 6 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:2); R_f = 0.73.

Step b:

To a stirring solution of 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)methylsulfanylbenzene (0.24 g, 0.7 mmol) at room temperature in CH_2Cl_2 (10 mL) was added *m*-CPBA (0.42 g, 2.45 mmol). The reaction mixture was stirred at room temperature for 16 hrs. It was quenched by sat. Na_2SO_3. The organic layer was washed by sat. $NaHCO_3$ and dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)methylsulfonylbenzene as a light yellow oil (0.23 g, 87%): ^{1}H NMR (200 MHz, $CDCl_3$-d_1): δ 7.62 (s, 2 H), 6.88 (m, 2 H), 6.55 (m, 1 H), 5.16 (s, 2 H), 4.10 (s, 2 H), 3.46 (s, 3 H), 3.28 (m, 1 H), 3.06 (s, 3 H), 2.33 (s, 6H) 1.17 (d, J = 6.9 Hz, 6 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:2); R_f = 0.46.

Step c:

To a stirring solution of 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)methylsulfonylbenzene (0.23 mL, 0.61 mmol) in THF (10 mL) at –78 °C was added *n*-BuLi (2.5 M in hexanes, 0.29 mL), the reaction mixture was stirred at –78 °C for 1 hr and at 0 °C for 40 min, then diethyl phosphorochloridate (0.11 mL, 0.73 mmol) was added at 0 °C. The reaction mixture was stirred at room temperature for 1 hr. The reaction mixture was quenched with saturated NH_4Cl and diluted with diethyl ether.

The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel, eluting with ethyl acetate to afford diethyl [3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenylsulfonyl]methylphosphonate as a light yellow oil (130 mg, 42%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 7.63 (s, 2 H), 7.00 (d, J = 3.0 Hz, 1 H), 6.88 (d, J = 8.4 Hz, 1 H), 6.60 (dd, J = 3.0, 8.4 Hz, 1 H), 5.15 (s, 2 H), 4.36 (d, J = 17.2 Hz, 2 H), 3.97 (m, 6 H), 3.36 (s, 3H), 3.22 (m, 1 H), 2.31 (s, 6H), 1.19 (m, 12 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (3:1); R_f = 0.43.

Step d:

The title compound was prepared by the procedure described for the synthesis of example 8, step f: ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.08 (s, 1 H), 7.61 (s, 2 H), 6.89 (d, J = 3.0 Hz, 1 H), 6.62 (d, J = 8.0 Hz, 1 H), 6.43 (d, J = 3.0, 8.0 Hz, 1 H), 3.96 (s, 2 H), 3.85 (d, J = 16.6 Hz, 2 H), 3.13 (m, 1 H), 2.28 (s, 6 H), 1.10 (d, J = 6.8 Hz, 6 H); LC-MS m/z = 413 [C19H25O6PS + H]$^+$; Anal Calcd for (C19H25O6PS + 1.0H_2O + 0.15HBr + 0.2Et_2O): C, 51.99; H, 6.42; Br, 2.62. Found: C, 51.67; H, 6.50; Br, 2.62.

Example 53

Compound 53: [3,5-dimethyl-4-(4'-Hydroxy-3'-*iso*-propylphenoxy)benzenesulfonyl]methylphosphonic acid

Step a:

To a stirring solution of 4-bromo-2,6-dimethylphenol (6 g, 29.85 mmol) in CH_2Cl_2 (80 mL) at 0 °C was added imidazole (4.1 g, 59.70 mmol) and triisopropylsilyl chloride (7.1 mL, 32.84 mmol). The reaction mixture was stirred at room temperature for 16 hrs. The solvent was removed under reduced pressure and the residue was partitioned between ethyl acetate and water. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:9) to afford (4-bromo-2,6-dimethylphenoxy)triisopropylsilane as a colorless oil (1.6 g, 15%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.19 (s, 2 H), 2.20 (s, 6 H), 1.29 (m, 3 H), 1.10 (d, J = 7.2 Hz, 18 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (5:95); R_f = 0.70.

Step b:

To a stirring solution of (4-bromo-2,6-dimethylphenoxy)triisopropylsilane (0.5 g, 1.4 mmol) in THF (15 mL) at –78 °C was added n-BuLi (2.5 M in hexanes, 0.56 mL),

the reaction mixture was stirred at –78 °C for 1 hr, then dimethyldisulfide (0.16 mL, 1.82 mmol) was added at -78 °C. The reaction mixture was stirred at room temperature for 1 h and quenched with saturated NH_4Cl and diluted with diethyl ether. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford crude (2,6-dimethyl-4-methylsulfanylphenoxy)triisopropyl-silane as an oil (0.46 g, 100%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.92 (s, 2 H), 2.41 (s, 3 H), 2.20 (s, 6 H), 1.29 (m, 3 H), 1.10 (d, J = 7.2 Hz, 18 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (2:98); R_f = 0.57.

Step c:

To a stirring solution of (2,6-dimethyl-4-methylsulfanylphenoxy)triisopropyl-silane (0.46 g, 1.4 mmol) in CH_2Cl_2 (15 mL) at room temperature was added *m*-CPBA (0.85 g, 4.9 mmol). The reaction mixture was stirred at room temperature for 16 hrs. It was quenched by sat. Na_2SO_3. The organic layer was washed by sat. $NaHCO_3$ and dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford crude (2,6-dimethyl-4-methanesulfonylphenoxy)triisopropylsilane as an oil (0.47 g, 94%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 7.57 (s, 2 H), 3.14 (s, 3 H), 2.28 (s, 6 H), 1.19 (m, 3 H), 1.10 (d, J = 7.2 Hz, 18 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (5:95); R_f = 0.49.

Step d:

To a stirring solution of (2,6-dimethyl-4-methanesulfonylphenoxy)triisopropylsilane (0.47g, 1.32 mmol) in THF (15 mL) at –78 °C was added *n*-BuLi (2.5 M in hexanes, 0.58 mL), the reaction mixture was stirred at –78 °C for 1 hr, then diethyl phosphorochloridate (0.25 mL, 1.72 mmol) was added at –78 °C. The reaction mixture was stirred at room temperature for 16 hrs. The reaction mixture was quenched with saturated NH_4Cl and diluted with diethyl ether. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl (3,5-dimethyl-4-triisopropylsilanyloxy-benzenesulfonyl)methylphosphonate as a colorless oil (0.1 g, 15%): ^{1}H NMR (200 MHz, $CDCl_3$-d_6): δ 7.57 (s, 2 H), 4.17 (m, 4 H), 3.71 (d, J = 17.2 Hz, 2 H), 2.29 (s, 6 H), 1.33 (m, 9 H), 1.10 (d, J = 7.2 Hz, 18 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:1); R_f = 0.45.

Step e:

To a stirring solution diethyl (3,5-dimethyl-4-triisopropylsilanyloxy-benzenesulfonyl)methylphosphonate in THF (3 mL) at room temperature was added TBAF (0.3 mL, 1 M in THF). It was stirred at room temperature for 2 hrs. The solvent was removed under reduced pressure and the residue was partitioned between ethyl acetate and water. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (5:1) to afford diethyl (3,5-dimethyl-4-hydroxybenzenesulfonyl)methylphosphonate as a light yellow oil (70 mg, 100%): ^1H NMR (300 MHz, $CDCl_3$-d_6): δ 7.54 (s, 2 H), 4.12 (m, 4 H), 3.65 (d, J = 16.8 Hz, 2 H), 2.22 (s, 6 H), 1.22 (d, J = 7.2 Hz, 6 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (5:1); R_f = 0.44.

Step f:

To a stirring mixture of bis(4-methoxy-3-*iso*-propylphenyl)iodonium tetrafluoroborate (0.15 g, 0.3 mmol) and copper powder (16 mg, 0.26 mmol) in CH_2Cl_2 (5 mL) at 0 °C was added a solution of triethylamine (0.031 mL, 0.22 mmol) and diethyl (3,5-dimethyl-4-hydroxybenzenesulfonyl)methylphosphonate (70 mg, 0.2 mmol) in CH_2Cl_2 (2 mL). The reaction mixture was stirred at room temperature for 16 hrs and filtered through a Celite plug. The solvent was removed under reduced pressure and the crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (5:1) to afford diethyl [3,5-dimethyl-4-(4'-methoxy-3'-*iso*-propylphenoxy)benzenesulfonyl]methylphosphonate as a light yellow oil (40 mg, 41%): ^1H NMR (200 MHz, DMSO-d_6): δ 7.76 (s, 2 H), 6.79 (m, 2 H), 6.35 (m, 1 H), 4.44 (d, J = 16.8 Hz, 2 H), 4.02 (m, 4 H), 3.73 (s, 3 H), 3.18 (m,1 H), 2.14 (s, 6 H), 1.15 (m, 12 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (3:2); R_f = 0.49.

Step g:

The title compound was prepared according to the procedure described for the synthesis of example 22, step d, (40 mg, 0.083 mmol): ^1H NMR (200 MHz, DMSO-d_6): δ 9.02 (s, 1 H), 7.70 (s, 2 H), 6.67 (m, 2 H), 6.19 (dd, J = 3.0, 8.4 Hz, 1 H), 3.72 (d, J = 15.8 Hz, 2 H), 3.14 (m, 1 H), 2.09 (s, 6 H), 1.11 (d, J = 6.6 Hz, 6 H); LC-MS m/z = 415 $[C18H23O7PS + H]^+$; Anal Calcd for (C18H23O7PS +1.3H_2O + 0.1EtOAc): C, 49.48; H, 5.96. Found: C, 49.18; H, 5.67.

Example 54:

Compound 54: [3,5-Dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)benzenesulfanyl]methylphosphonic acid

Step a:

To a stirring solution of (2,6-dimethyl-4-methylsulfanylphenoxy)triisopropylsilane (2.18 g, 6.72 mmol) in CCl_4 (25 mL) at room temperature was added *N*-chlorosuccinimide (0.99 g, 7.39 mmol). The reaction mixture was stirred at room temperature for 16 hrs and filtered through a Celite plug. The solvent was removed under reduced pressure to afford crude (4-chloromethylsulfanyl-2,6-dimethylphenoxy)triisopropylsilane as an oil (2.4 g, 100%). This crude oil was dissolved into phosphorous acid triethyl ester (1.5 mL). It was heated at 180 °C for 30 min by microwave. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl (3,5-dimethyl-4-triisopropylsilanyloxy-phenylsulfanyl)methylphosphonate as a yellow oil (1.6 g, 52%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 7.09 (s, 2 H), 4.98 (m, 4 H), 3.31 (d, J = 13.8 Hz, 2 H), 2.17 (s, 6 H), 1.25 (m, 9 H), 1.09 (d, J = 7.0 Hz, 18 H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate/Hexanes (2:3); R_f = 0.45.

Step b:

The title compound was prepared according to the procedure described for the synthesis of example 53, steps e, f and g: ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.91 (s, 1 H), 7.16 (s, 2 H), 6.64 (m, 2 H), 6.21 (dd, J = 3.3, 8.7 Hz, 1 H), 4.13 (m, 3 H), 2.02 (s, 6 H), 1.11 (d, J = 6.9 Hz, 6 H); LC-MS m/z = 383 [C18H23O5PS + H]$^+$; Anal Calcd for (C18H23O5PS + 0.15TFA + 0.2Et$_2$O): C, 55.00; H, 5.98. Found: C, 54.88; H, 5.76.

Example 55

Compound 55: [3,5-Dimethyl-4-(4'-hydroxy-3'-methylsulfanyl-benzyl)-phenoxy]methylphosphonic acid

Step a:

To a stirring solution of diethyl [3,5-dimethyl-4-(3'-amino-4'-methoxymethoxybenzyl)phenoxy]methylphosphonate (Example 51, step a; 0.29g, 0.66 mmol) at 80 °C in dimethyldisulfide (3 mL) was added isoamyl nitrite (0.4 mL, 2.64 mmol). The reaction mixture was stirred at 80 °C for 1 h. The solvent was removed

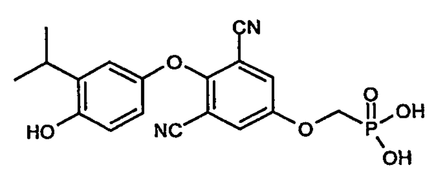
under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl [3,5-dimethyl-4-(3'-methylsulfanyl-4'-methoxymethoxybenzyl)phenoxy]methylphosphonate as a red oil (0.12 g, 39%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 6.91 (d, J = 8.4 Hz, 1 H), 6.86 (d, J = 2.1 Hz, 1 H), 6.75 (s, 2 H), 6.58 (dd, J = 2.2, 8.4 Hz, 1 H), 5.16 (s, 2 H), 4.36 (d, J = 10.0 Hz, 2 H), 4.11 (m, 4 H), 3.89 (s, 2 H), 3.37 (s, 3 H), 2.30 (s, 3 H), 2.17 (s, 6 H), 1.25 (t, J = 7.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 50% ethyl acetate in hexanes; R_f = 0.61.

Step b:

The title compound was prepared according to the procedure described for the synthesis of example 8, step f as a yellow foam (40 mg, 42%). ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.58 (s, 1 H), 6.80 (d, J = 2.1 Hz, 1 H), 6.72 (s, 2 H), 6.66 (d, J = 8.4 Hz, 1 H), 6.50 (dd, J = 2.1, 8.4 Hz, 1 H), 4.06 (d, J = 10.2 Hz, 2 H), 3.84 (s, 2 H), 2.28 (s, 3 H), 2.18 (s, 6 H); LC-MS m/z = 369 [$C_{17}H_{21}O_5PS$ + H]$^+$; Anal Calcd for ($C_{17}H_{21}O_5PS$ + 0.1EtOAc + 0.1TFA): C, 54.40; H, 5.68. Found: C, 54.65; H, 5.33.

Example 56:

Compound 56: 3,5-Dicyano-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenoxy]methylphosphonate



Step a:

To a solution of 4-benzoyloxyphenol (0.2 g, 0.93 mmol) in dichloromethane (9.3 mL) at 0 °C was added bis(pyridine)iodonium tetrafluoroborate (0.76 g, 2.06 mmol). The reaction mixture was stirred at room temperature for 1 h. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:9) to afford 4-benzoyloxy-3,5-diiodophenol as an off-white solid (0.22 g, 50%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.60 (s, 1 H), 8.06 (m, 2 H), 7.72 (s, 2 H), 7.59 (m, 3 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (4:1); R_f = 0.45.

Step b:

To a mixture of bis(4-methoxy-3-*iso*-propylphenyl)iodonium tetrafluoroborate (0.77 g, 1.51 mmol) and copper powder (0.13 g, 2.01 mmol) in CH_2Cl_2 (4.4 mL) at 0 °C was added a solution of TEA (0.15 mL, 1.10 mmol) and 4-benzoyloxy-3,5-diiodophenol (0.47 g, 1.00 mmol) in dichloromethane (4.0 mL). The reaction mixture was stirred at room temperature for 24 h and filtered through a Celite plug. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel, eluting with acetone-hexanes (1:9) to afford 3,5-diiodo-4-(4'-methoxy-3'-*iso*-propylphenoxy)phenyl benzoate as an off-white solid (0.61 g, 98%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.10 (m, 2 H), 7.96 (s, 2 H), 7.73 (m, 1 H), 7.60 (m, 2 H), 6.85 (d, J = 9.0 Hz, 1H), 6.73 (d, J = 3.0 Hz, 1H), 6.35 (m, 1 H), 3.74 (s, 3 H), 3.21 (m, 1 H), 1.13 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-acetone (1:9); R_f = 0.42.

Step c:

To a stirred solution of 3,5-diiodo-4-(4'-methoxy-3'-*iso*-propylphenoxy)phenyl benzoate (0.4 g, 0.76 mmol) in DMF(5.0 mL) at rt was added CuCN (0.27 g, 3.0 mmol). The reaction mixture was heated at 160 °C for 5 min under microwave irradiation, the reaction mixture was cool to room temperature and poured into 1N HCl (50 mL) and extracted with ethyl acetate (100 mLx2). The organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (3:7) to afford 3,5-dicyano-4-(4'-methoxy-3'-*iso*-propylphenoxy)phenol as a viscous (105 mg, 35%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.35 (s, 2 H), 6.99 (d, J = 3.0 Hz, 1 H), 6.78 (d, J = 8.7 Hz, 1 H), 6.99 (dd, J = 3.0, 8.7 Hz, 1 H), 3.84 (s, 3 H), 3.38 - 3.30 (m, 1 H), 1.21 (d, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (7:3); R_f = 0.38.

Step d:

3,5-dicyano-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenol was prepared according to the procedure described for the synthesis of compound 54, step d (132 mg, 32%): ^{1}H NMR (300 MHz, CD_3OD) δ 7.38 (s, 2H), 6.81 (d, J = 3.0 Hz, 1H), 6.70 (d, J = 9.0 Hz, 1H), 6.52 (dd, J = 9.0, 3.0 Hz, 1H), 3.26 (heptuplet, J = 7.0 Hz, 1H), 1.18 (d, J = 7.0 Hz, 6H); TLC conditions: Merck silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (1:1), R_f = 0.35.

Step e:

Diethyl trifluoromethanesulfonyloxymethylphosphonate (148 mg, 0.5 mmol) was added to an heterogeneous mixture of 3,5-dicyano-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenol (132 mg, 0.45 mmol) and cesium carbonate (440 mg, 1.35 mmol) in DMF at rt. After stirring at rt for 1 week, the reaction mixture was diluted with ethyl acetate and the pH lowered to 1 with 1 N hydrochloric acid. The organics were washed with water then brine, dried over sodium sulfate and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, hexanes/ethyl acetate 50/50 to 0/100) to give diethyl 3,5-dicyano-4-(4'-hydroxy-3'-*iso*-propylphenoxy)phenoxy]methylphosphonate (44 mg, 22%): ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42 (s, 2H), 6.73 (d, J = 3.0 Hz, 1H), 6.68 (d, J = 9.0 Hz, 1H), 6.57 (dd, J = 9.0, 3.0 Hz, 1H), 4.35-4.20 (m, 6H), 3.23 (heptuplet, J = 7.0 Hz, 1H), 1.38 (t, J = 7.0 Hz, 6H), 1.18 (d, J = 7.0 Hz, 6H); TLC conditions: Merck silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (1:1), R_f = 0.2.

Step f:

The title compound was prepared by the procedure described for the synthesis of compound 8, step f (18 mg, 47%): ^{1}H NMR (300 MHz, CD_3OD) δ 7.74 (s, 2H), 6.85 (d, J = 3.0 Hz, 1H), 6.72 (d, J = 9.0 Hz, 1H), 6.56 (dd, J = 9.0, 3.0 Hz, 1H), 4.35 (d, J = 6.8 Hz 2H), 3.27 (heptuplet, J = 7.0 Hz, 1H), 1.18 (d, J = 7.0 Hz, 6H); Anal. Calcd for ($C_{18}H_{17}N_2O_6P$ + 1.4 H_2O): C, 52.28; H, 4.83; N, 6.77. Found: C, 52.55; H, 4.90; N, 6.12.

Example 57

Compound 57: [4,6-dichloro-3-fluoro-5-(4'-hydroxy-3'-*iso*-propylphenoxy)-pyrid-2-yloxy]methyl phosphonic acid

Step a:

To a stirring solution of 3,5-dichloro-2,6-difluoro-4-(4'-methoxymethoxy-3'-*iso*-propyl-phenoxy)-pyridine (0.11 g, 0.29 mmol) and diethyl hydroxymethyl-phosphonate (0.045 mL, 0.31 mmol) in THF (3 mL) at 0 °C was added NaH (13 mg, 0.31 mmol). The reaction mixture was stirred at room temperature for 16 hrs, diluted with EtOAc and washed with water (30 mLx2). The solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (2:1) to afford diethyl [4,6-dichloro-3-fluoro-5-(4'-hydroxy-3'-*iso*-propylphenoxy)-pyrid-2-yloxy]methyl phosphonate as a yellow oil (43 mg, 28%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.00 (d, J = 9.0 Hz, 1 H), 6.96 (d, J = 3.3 Hz, 1 H), 6.67

(dd, $J = 3.3, 9.0$ Hz, 1 H), 5.19 (s, 2 H), 4.77 (d, $J = 8.1$ Hz, 2 H), 4.15 (m, 4 H), 3.40 (s, 3 H), 3.28 (m, 1 H), 1.27 (t, $J = 7.2$ Hz, 6 H), 1.17 (d, $J = 6.6$ Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 66% ethyl acetate in hexanes; R_f = 0.31.

Step b:

The title compound was prepared according to the procedure described for the synthesis of example 8, step f as a white solid (30 mg, 71%): mp: 139-141 °C; ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.22 (s, 1 H), 6.84 (d, $J = 2.8$ Hz, 1 H), 6.68 (d, $J = 8.8$ Hz, 1 H), 6.47 (dd, $J = 2.8, 8.8$ Hz, 1 H), 4.46 (d, $J = 8.8$ Hz, 2 H), 3.17 (m, 1 H), 1.13 (d, $J = 6.6$ Hz, 6 H); LC-MS m/z = 427 $[C_{15}H_{15}C_{12}FNO_6P + H]^+$; Anal Calcd for $(C_{15}H_{15}C_{12}FNO_6P + 0.5H_2O)$: C, 41.40; H, 3.71; N, 3.22. Found: C, 41.09; H, 3.87; N, 2.89.

Example 58:

Compound 58: [4-(4'-Acetoxy-3'-*iso*-propylbenzyl)-3,5-dimethylphenoxy]methylphosphonic acid:

A mixture of [3,5-Dimethyl-4-(4'-hydroxy-3'-*iso*-propylbenzyl)] phenoxy]methyl phosphonic acid (5.0 g, 13.7 mmol) and acetic anhydride (5.0 g, 48.9 mmol) in toluene (70 mL) was stirred at 20 °C for 3 hrs. Water (5 mL) was added and the mixture was stirred 1 hr. The solvent was removed under reduced pressure. Toluene (50 mL) was added to the residue then removed under reduced pressure. Toluene addition and evaporation was repeated twice more. The resulting solid was dried under vacuum at 45 °C to give the title compound (5.6 g, 100%). A purified sample (420 mg) was obtained by stirring the crude product in boiling isopropyl ether, cooling to 20 °C, collecting the solid by filtration, and drying under vacuum. mp: 169-172 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.06 (d, $J = 2.1$ Hz, 1H), 6.85 (d, $J = 8.4$ Hz, 1H), 6.70 (s, 2H), 6.65 (dd, $J = 9.0$ and 2.4 Hz, 1H), 4.02 (d, $J = 10.2$ Hz, 2H), 3.90 (s, 2H), 2.94-2.84 (m, 1H), 2.25 (s, 3H), 2.15 (s, 6H), 1.07 (d, $J = 6.9$ Hz, 6H). Anal. Calcd for $(C_{21}H_{27}O_6P)$: C, 62.06; H, 6.70. Found: C, 62.22; H, 6.82.

Example 59

Cis and *Trans* (*S*)-2-[(4-(4'-Acetoxy-3'-*iso*-propylbenzyl)-3,5-dimethylphenoxy)methyl]-4-(3-chlorophenyl)-2-oxo-2λ^5-[1,3,2]-dioxaphosphonane:

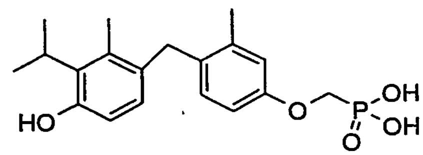
A solution of oxalyl chloride (3.0 g, 23.6 mmol) in dichloromethane (14 mL) was added over 20 minutes to a stirring suspension of [4-(4'-acetoxy-3'-*iso*-propylbenzyl)-3,5-dimethylphenoxy]methylphosphonic acid (3.2 g, 7.88 mmol) in dichloromethane (50 mL). The resulting solution was stirred at 20 °C for 1hr. then the solvent was removed under reduced pressure. Dichloromethane (30 mL) was added to the residue then evaporated under reduced pressure. The resulting oil was dissolved in THF (32 mL) and the solution was added over 40 minutes to a stirring solution of (*S*)-1-(3-chlorophenyl)-1,3-propanediol (1.5 g, 7.88 mmol) and triethylamine (2.4 g, 23.6 mmol) in THF (32 mL) while keeping the temperature below –70 °C. The reaction mixture was stirred at –70 °C for 2 hrs. then warmed to 15 °C. To the reaction mixture was added 0.5 M aqueous HCl (32 mL) and ethyl acetate (32 mL). The phases were separated and the aqueous layer was extracted with ethyl acetate (32 mL). The combined organic layers were washed with brine, dried over magnesium sulfate, and filtered. The solvent was removed under reduced pressure. The crude product was purified by chromatography on silica gel, eluting with ethyl acetate-hexanes (50%-100%) to afford:

Compound 59-*trans*: (610 mg, 14%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.48-7.36 (m, 4H), 7.07 (d, J = 2.1 Hz, 1H), 6.85 (d, J = 8.4 Hz, 1H), 6.83 (s, 2H), 6.64 (dd, J = 9.0 and 2.0 Hz, 1H), 5.85-5.82, (m, 1H), 4.74-4.68 (m, 1H), 4.61 (d, J = 9.3 Hz, 2H), 4.52-4.42 (m, 1H), 3.92 (s, 2H), 2.94-2.85 (m, 1H), 2.25 (s, 3H), 2.24-2.20 (m, 2H), 2.17 (s, 6H), 1.07 (d, J = 6.9 Hz, 6H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = dichloromethane-acetone (9:1); R_f = 0.5.

Compound 59-*cis*: (2.5g, 57%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.47 (m, 1H), 7.38-7.26 (m, 3H), 7.06 (d, J = 2.1 Hz, 1H), 6.85 (d, J = 8.7 Hz, 1H), 6.76 (s, 2H), 6.67 (dd, J = 8.1 and 2.1 Hz, 1H), 5.76-5.72 (m, 1H), 4.61-4.36 (m, 4H), 3.92 (s, 2H), 2.94-2.85 (m, 1H), 2.25 (s, 3H), 2.20-2.19 (m, 2H), 2.16 (s, 6H), 1.07 (d, J = 6.9 Hz, 6H). TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = dichloromethane-acetone (9:1); R_f = 0.35; Anal Calcd for ($C_{30}H_{34}ClO_6P$ + 0.13 H_2O): C, 64.42; H, 6.17. Found: C, 64.12; H, 6.07.

Example 60

Compound 60: [4-(4'-Hydroxy-3'-*iso*-propyl-2'-methylbenzyl)-3-methylphenoxy]methylphosphonic acid



Step a:

To a stirring solution of 1-bromo-3-*iso*-propyl-4-methoxy-2-methyl-benzene (compound 7-16, step c; 0.7 g, 2.88 mmol) in THF (20 mL) at –78 °C was added *n*-BuLi (1.6 mL, 2.5 M in hexanes). The mixture was stirred at –78 °C for 1 hr and 4-methoxy-2-methyl-benzaldehyde (0.37 mL, 2.74 mmol) was added. The reaction mixture was stirred at –78 °C for 1 hr, allowed to warm to room temperature and stirred for 1 hr. The reaction mixture was quenched with saturated NH_4Cl and diluted with diethyl ether. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford crude (4'-methoxy-3'-*iso*-propyl-2'-methylphenyl)-(4-methoxy-2-methylphenyl)-methanol as a light yellow oil (1.0 g, 100%). This crude oil was dissolved into EtOAc (25 mL) and AcOH (5 mL) and Pd/C (0.1 g) was added. After stirring at rt for 6 hours, the reaction mixture was filtered through the Celite and concentrated under reduced pressure to afford crude 4-(4'-methoxy-2'-methyl-3'-*iso*-propylbenzyl)-3-methyl-anisole as a yellow oil (0.8 g, 93%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.88 –6.80 (m, 5 H), 3.77 (s, 2 H), 3.74 (s, 3 H), 3.71 (s, 3 H), 3.34 (m, 1 H), 2.22 (s, 3 H), 2.14 (s, 3 H), 1.28 (d, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 8% ethyl acetate in hexanes; R_f = 0.56.

Step b:

To a stirring solution of 4-(4'-methoxy-2'-methyl-3'-*iso*-propylbenzyl)-3-methyl-anisole (0.8 g, 2.68 mmol) in CH_2Cl_2 (10 mL) at - 20 °C was added BBr_3 (10.7 mL, 1M in CH_2Cl_2). The reaction mixture was stirred at room temperature for 16 hrs. It was added ice and diluted with CH_2Cl_2. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate/hexanes (1:1) to afford 4-(4'-hydroxy-2'-methyl-3'-*iso*-propylbenzyl)-3-methylphenol as a yellow solid (0.54 g,

75%): ^{1}H NMR (200 MHz, DMSO-d_6): δ 9.03 (s, 1 H), 8.84 (s, 1 H), 6.41-6.60 (m, 5 H), 3.65 (s, 2 H), 3.33 (m, 1 H), 2.12 (s, 3 H), 2.08 (s, 3 H), 1.27 (d, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 20% ethyl acetate in hexanes; R_f = 0.31.

Step c:

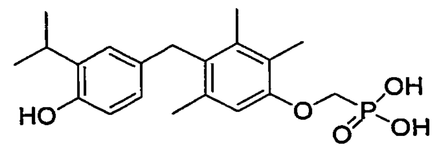
To a solution of 44-(4'-hydroxy-2'-methyl-3'-*iso*-propylbenzyl)-3-methylphenol (0.54 g, 2 mmol) in DMF (15 mL) at room temperature was added Cs_2CO_3 (2.6 g, 8 mmol) and diethyl trifluoromethanesulfonyloxymethylphosphonate (0.66 g, 2.2 mmol). The reaction mixture was stirred at room temperature for 1 hr. The solvent was removed under reduced pressure and the residue was partitioned between ethyl acetate and saturated $NaHCO_3$. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (4:1) to afford diethyl [4-(4'-hydroxy-3'-*iso*-propyl-2'-methylbenzyl)-3-methylphenoxy]methylphosphonate as a colorless oil (0.14 g, 17%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.89 (s, 1 H), 6.86 (d, J = 2.7 Hz, 1 H), 6.76 (dd, J = 2.7, 9.0 Hz, 1 H), 6.67 (d, J = 9.0 Hz, 1 H), 6.51 (m, 2 H), 4.36 (d, J = 9.6 Hz, 2 H), 4.11 (m, 4 H), 3.73 (s, 2 H), 3.34 (m, 1 H), 2.22 (s, 3 H), 2.09 (s, 3 H), 1.27 (m, 12 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = 66% ethyl acetate in hexanes; R_f = 0.45.

Step d:

The title compound was prepared according to the procedure described for the synthesis of example 8, step f as a white solid (80 mg, 67%): ^{1}H NMR (300 MHz, DMSO-d_6): 8.88 (s, 1 H), 6.85 (d, J = 2.1 Hz, 1 H), 6.73 (dd, J = 2.1, 8.7 Hz, 1 H), 6.66 (d, J = 8.7 Hz, 1 H), 6.51 (m, 2 H), 4.02 (d, J = 10.2 Hz, 2 H), 3.73 (s, 2 H), 3.34 (m, 1 H), 2.22 (s, 3 H), 2.10 (s, 3 H), 1.30 (d, J = 6.9 Hz, 6 H); mp: 166 – 168 °C; LC-MS *m/z* = 363 [C19H25O5P - H]$^-$; Anal Calcd for (C19H25O5P + 0.13HBr): C, 60.87; H, 6.76; Br, 2.77. Found: C, 61.19; H, 6.84; Br, 3.10.

Example 61:

Compound 61-1: [4-(4'-hydroxy-3'-*iso*-propylbenzyl)-2,3,5-trimethylphenoxy]methylphosphonic Acid



Step a:

A mixture of 3,5-dimethyl-2-iodo-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol (compound 47, step a; 1.0 g, 2.27 mmol) and $PdCl_2(PPh_3)_2$ (0.10 g, 0.14 mmol) in TEA (1.6 mL) and methanol (8.0 mL) was heated under a CO atmosphere (60 psi) at 80 °C for 72 h. The reaction mixture was cooled to room temperature and filtered through a Celite plug. The solvent was removed under reduced pressure and the crude product was purified by column chromatography on silica gel, eluting with 10% ethyl acetate in hexanes to afford methyl 2,4-dimethyl-6-hydroxy-3-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)benzoate (0.32 g, 38 %): ^{1}H NMR (300 MHz, CD_3OD): δ 6.93 (m, 2 H), 6.67 (s, 2 H), 5.18 (s, 1 H), 3.98 (s, 2 H), 3.92 (s, 3 H), 3.48 (s, 3 H), 3.30 (m, 1 H), 2.22 (m, 6 H), 1.18 (d, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (1:5); R_f = 0.60.

Step b:

To a solution of methyl 2,4-dimethyl-6-hydroxy-3-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)benzoate in ethanol-water (3.0 mL, 95:5) at room temperature was added $NaBH_4$. The reaction mixture was heated at 80 °C for 4 h and cooled to room temperature. The reaction mixture was quenched with aqueous NH_4Cl and extracted with ether. The organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with 30% acetone in hexanes to afford 2,4-dimethyl-6-hydroxy-3-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)benzyl alcohol: ^{1}H NMR (300 MHz, CD_3OD): δ 6.97 (d, J = 2.4 Hz, 1 H), 6.92 (d, J = 13.2 Hz , 1 H), 6.68 (dd, J = 13.2, 2.4 Hz , 1 H), 6.59 (s, 1 H), 5.17 (s, 2 H), 4.78 (s, 2 H), 3.96 (s, 2 H), 3.47 (s, 3 H), 3.30 (m, 1 H), 2.24 (s, 3 H), 2.19 (s, 3 H), 1.18 (d, J = 10.8 Hz, 6 H); TLC

conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (3:7); R_f = 0.40.

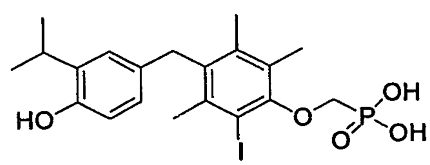
Step c:

A mixture of 2,4-dimethyl-6-hydroxy-3-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)benzyl alcohol ((0.20 g, 0.58 mmol) and Pd-C (0.08 g, 10%) in ethyl acetate-acetic acid (3.5 mL, 95:5) was stirred at room temperature under a H_2 atmosphere for 6 h. The reaction mixture was filtered through a Celite plug and the solvent was removed under reduced pressure to afford 4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)-2,3,5-trimethylphenol (0.19 g, 100%) as colorless oil: ^{1}H NMR (300 MHz, CD_3OD): δ 6.94 (m, 1 H), 6.91 (d, J = 13.2 Hz, 1 H), 6.68 (dd, J = 13.2, 2.4 Hz, 1 H), 6.55 (s, 1 H), 5.17 (s, 2 H), 3.95 (s, 2 H), 3.47 (s, 3 H), 3.30 (m, 1 H), 2.19 (s, 3 H), 2.16 (s, 3 H), 2.11 (s, 3 H), 1.17 (d, J = 10.8 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = acetone-hexanes (3:7); R_f = 0.60.

The title compound was prepared according to the procedure described for the synthesis of compound 7: mp: 56.0-58.0 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 6.85 (d, J = 2.4 Hz, 1 H), 6.76 (s, 1 H), 6.60 (d, J = 12.0 Hz, 1 H), 6.52 (dd, J = 12.6, 2.4 Hz, 1 H), 4.22 (d, J = 10.2 Hz, 2 H), 3.94 (s, 2 H), 3.23 (m, 1 H), 2.25 (s, 3 H), 2.24 (s, 3 H), 2.15 (s, 3 H), 1.17 (d, J = 10.8 Hz, 6 H); LC-MS m/z = 379 $[C_{20}H_{27}O_5P + H]^+$; Anal Calcd for $[C_{20}H_{27}O_5P + 1.1\ H_2O]$: C, 60.32; H, 7.39. Found: C, 60.05; H, 7.14.

Example 62

Compound 62: [6-iodo-4-(4'-hydroxy-3'-*iso*-propylbenzyl)-2,3,5-trimethylphenoxy]methylphosphonic Acid

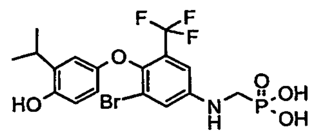


[6-Iodo-4-(4'-hydroxy-3'-*iso*-propylbenzyl)-2,3,5-trimethylphenoxy]methylphosphonic acid was prepared from 4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)-2,3,5-trimethylphenol (compound 61-1, step c) was prepared according to the procedure described for the synthesis of compound 45, step a and transformed into the title compound according to the procedure described for

the synthesis of compound 7-1: mp: 185-187 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 6.88 (d, J = 2.4 Hz, 1 H), 6.61 (d, J = 12.3 Hz, 1 H), 6.50 (d, J = 2.4 Hz, 1 H), 4.14 (d, J = 10.5 Hz, 1 H), 4.09 (s, 2 H), 3.24 (m, 1 H), 2.46 (s, 3 H), 2.39 (s, 3 H), 2.19 (s, 3 H), 1.18 (d, J = 6.9 Hz, 6 H); LC-MS m/z = 504 $[C_{20}H_{27}O_5P]^+$; Anal. Calcd for ($C_{20}H_{26}IO_5P$+0.8 H_2O): C, 46.26; H, 5.41. Found: C, 46.48; H, 5.78.

Example 63

Compound 63: [3-Bromo-4-(4'-hydroxy-3'-*iso*-propylphenoxy)-5-trifluoromethyl-phenylamino]methylphosphonic acid



Step a:

Intermediate 1,5-dibromo-2-(3'-*iso*-propyl-4'-methoxy-phenoxy)-3-trifluoromethyl-benzene was prepared from 2,4-dibromo-6-trifluoromethyl-phenol (*J. Amer. Chem. Soc.*, **1947**, 2346) according to the procedure described for the synthesis of compound 4, step a: ^{1}H NMR (200 MHz, DMSO-d_6): δ 8.39 (m, 1 H), 8.07 (m, 1 H), 6.85 (m, 2 H), 6.45 (m, 1 H), 3.73 (s, 3 H), 3.15 (m, 1 H), 1.08 (d, J = 10.5 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes; R_f = 0.54.

Step b:

To a mixture of $Pd(OAc)_2$ (0.031 g, 0.14 mmol) in toluene (40 mL) at rt was added (+/-)2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (0.13 mL, 0.21 mmol). The reaction mixture was stirred at rt for several minutes and Cs_2CO_3 (3.62 g, 11.10 mmol), 1,5-dibromo-2-(3'-iso-propyl-4'-methoxyphenoxy)-3-trifluoromethyl-benzene (1.30 g, 2.77 mmol, dissolved in 10 mL toluene), and diethyl aminomethylphosphonate oxalate (0.76 g, 2.97 mmol) were added. The reaction mixture was stirred at 100 °C for 16 h. The solution was cooled to rt, diluted with diethyl ether (25 mL), filtered and concentrated. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:1) to afford diethyl [3-bromo-4-(4'-methoxy-3'-iso-propyl-phenoxy)-5-trifluoromethylphenylamino]methylphosphonate as an oil (0.28 g, 18%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.33 (m, 1 H), 7.16 (m, 1 H), 6.85 (m, 1 H), 6.65 (m, 1 H), 6.55 (m, 1 H), 6.39 (m, 1 H), 4.08 (m, 4 H), 3.74 (s, 3 H), 3.68 (m, 2 H),

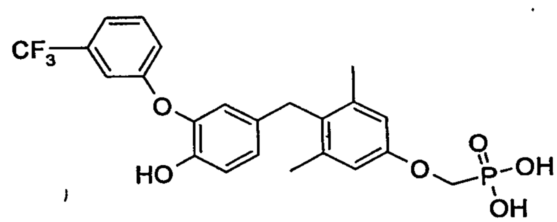
3.21 (m, 1 H), 1.19 (m, 6 H), 1.11 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = ethyl acetate-hexanes (4:1); $R_f = 0.25$.

Step c:

The title compound was prepared according to the procedure described for the synthesis of Example 19, step e: mp: 98-102 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 7.11 (m, 1 H), 6.95 (m, 2 H), 6.48 (m, 1 H), 6.45 (m, 1 H), 6.20 (m, 1 H), 3.41 (d, J = 12.0 Hz, 2 H), 3.12 (m, 1 H), 1.17 (m, 18 H), 1.04 (d, J = 6.0 Hz, 6 H); LC-MS m/z = 484 $[C_{17}H_{18}BrF_3NO_5P - H]^+$; HPLC conditions: Column = Shimadzu LC-A8, SPD-10A; YMC Pack RP-18 filter, 150×4.6; Mobile phase = Solvent A Acetonitrile/0.05% TFA; Solvent B = H_2O/0.05% TFA. Gradient: 0min: 20% B; 13 min: 70% B; 16min: 100% B; 18min: 20% B. Flow rate = 2.0 mL/min; UV@ 254 nm. rt = 9.16min.

Example 64

Compound 64: [3,5-Dimethyl-4-[4'-hydroxy-3'-(3-trifluoromethylphenoxy)benzyl]phenoxy]methylphosphonic acid



Step a:

To 5-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-2-methoxymethoxy-benzaldehyde (compound 15, step e; 0.460 g, 1.01mmol) in dichloromethane 30 mL was add mCPBA (0.870 g, 2.52 mmol) and saturated sodium biacarbonate solution (2 mL). After stirring at rt overnight, the reaction mixture was poured into dichloromethane 50 mL and washed 3 x with 10 mL of saturated aqueous sodium bicarbonate. The dichloromethane was dried over sodium sulfate, filtered and concentrated under reduced pressure. The resulting residue was combined with methanol (10 mL) and 2 mL of 1 N NaOH and stirred for 1.5 hours at room temperature. The reaction was acidified with 12 N HCl (pH<3) and poured into 50 mL ethyl acetate. The layers were separated and the organics were dried over sodium sulfate, filtered and concentrated. Flash column chromatography using silica and a step gradient of hexane/ethyl acetate [20:1],

hexane/ethyl acetate [9:1] provided 5-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-2-methoxymethoxy-phenol (0.189 g, 42%): ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.95(s, 1H), 6.86(d, 1H, J = 8.1 Hz), 6.56(s, 2H), 6.41(d, 1H, J = 2.1 Hz), 6.34(dd, 1H, J = 2.1 Hz and J = 8.7 Hz), 5.05(s, 2H), 3.78(s, 2H), 3.38(s, 3H), 2.13(s, 6H), 1.11(m, 3H), 1.00(m, 18H); Uniplate silica gel, 250 microns; Mobile phase = 10% ethyl acetate in hexane: Rf = 0.15

Step b:

(2,6-Dimethyl-4-triisopropylsilanyloxybenzyl)-4-methoxymethoxy-3-(3-trifluoromethylphenoxy)benzene was prepared from 5-(2,6-dimethyl-4-triisopropylsilanyloxybenzyl)-2-methoxymethoxy-phenol according to the procedure described in Dominic M. T. Chan *et al. Tetrahedron Lett.* **1998**, *39*, 2933-2936, (0.070 g, 37%)^{1}H NMR (300 MHz, DMSO-d_6): δ 7.53(t, 1H, J = 7.8 Hz), 7.35(d, 1H, J = 7.8 Hz), 7.21-7.10(m, 2H), 6.98(s, 1H), 6.89(m, 1H), 6.59(m, 1H), 6.64(s, 2H), 5.09(s, 2H), 3.89(s, 2H), 3.18(s, 3H), 2.11(s, 6H), 1.16(m, 3H), 1.01(m, 18H); Uniplate silica gel, 250 microns; Mobile phase = 10% ethyl acetate in hexane: Rf = 0.47

Step c:

3,5-Dimethyl-4-[4'-methoxymethoxy-3'-(3-trifluoromethylphenoxy)benzyl]phenol was synthesized according to the procedure described for the synthesis of compound 35, step e, (0.059 g, 100%); ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.02(s, 1H), 7.55(t, 1H, J = 7.8 Hz), 7.38(1H, d, J = 8.4 Hz), 7.14(m, 2H), 7.02(s, 1H), 6.88(dd, 1H, J = 1.5 Hz and J = 6.6 Hz), 6.72(d, 1H, 2.1 Hz), 6.44(s, 2H), 5.08(s, 2H), 3.85(s, 2H), 3.18(s, 3H), 2.08(s, 6H); (Uniplate silica gel, 250 microns; Mobile phase = 25% ethyl acetate in hexane: Rf = 0.28

Step d:

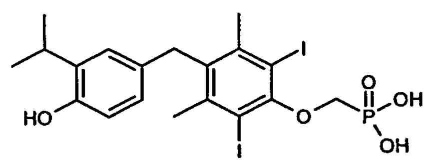
Diethyl [3,5-dimethyl-4-[4'-methoxymethoxy-3'-(3-trifluoromethylphenoxy)benzyl]phenoxy]methylphosphonate was prepared according to the procedure described for the synthesis of compound 8, steps e (0.015 g, 15%);^{1}H NMR (300 MHz, DMSO-d_6): δ 7.55(t, 1H, J = 8.4 Hz), 7.37(d, 1H, J = 7.5 Hz), 7.14(m, 2H), 7.02(s, 1H), 6.86(dd, 1H, J = 1.7Hz and J = 7 Hz), 6.73(s, 2H), 5.08(s, 2H), 4.34(d, 2H, J = 9.9 Hz), 4.09(m, 4H), 3.91(s, 2H), 3.18(s, 3H), 2.18(s, 6H), 1.24(t, 6H, J = 7 Hz); Uniplate silica gel, 250 microns; Mobile phase = 25% hexane in ethyl acetate: Rf = 0.2

Step e:

The title compound was prepared according to the procedure described for the synthesis of compound 8, steps f, (0.022g, 90%); ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.48(s, 1H), 7.53(t, 1H, J = 7.8 Hz), 7.34(d, 1H, J = 7.2 Hz), 7.07(d, 1H, J = 9 Hz), 7.01(s, 1H), 6.90(d, 1H, J = 8.4 Hz), 6.71(m, 4H), 4.00(d, 2H, J = 10.2 Hz), 3.84(s, 2H), 2.15(s, 6H); LC-MS m/z = 481 [$C_{23}H_{22}F_3O_6P$ - H]$^-$; Uniplate silica gel, 250 microns; Mobile phase = isopropyl alcohol /water/ ammonium hydroxide [7:2:1]: Rf = 0.47; HPLC, zorbax, XDB-C8, 150mm x 4.6 mm, 5um, flow 1 mL/min, solvent A: 0.05 M KH_2PO_4 aqueous pH 6.2, Solvent B: acetonitrile, Gradient 40% B to 60%B over 11min then 60%B. total run time 12 min. RT 1.87 min; Anal Calcd for ($C_{23}H_{22}F_3O_6P$ + 0.3 M H_2O + 0.1 M EtOAc) C, 56.60; H, 4.70. Found: C, 56.68; H, 3.97.

Example 65

Compound 65-1: 2,6-diiodo-3,5-dimethyl-[4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methyl phosphonic acid



Step a:

To a stirred solution of 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol (0.22 g, 0.70 mmol), (G. Chiellini *et al. Bioorg. Med. Chem. Lett.* **2000**, *10*, 2607) in EtOH (6.2 mL) and CH_3NH_2 40% in water (2.5 mL) was added iodine (0.39 g, 1.54 mmol) and KI (0.25 g 1.54 mmol) in H_2O (3 mL) at 0° C. The reaction mixture was stirred at room temperature for 16 h, quenched with brine (50 mL) and extracted with ethyl acetate (50 mLx2). The combined organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:4) to afford 2,6-diiodo-3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol as a colorless oil (198 mg, 50%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.97 (d, J = 2.1 Hz, 1 H), 6.92 (d, J = 5.6 Hz, 1 H), 6.59 (dd, J = 2.4, 8.4 Hz, 1 H), 6.0 (s, 1 H), 5.19 (s, 2 H), 4.16 (s, 2 H), 3.50 (s, 3 H), 3.35 - 3.30 (m, 1 H), 2.48 (s, 6 H), 1.21 (d, J = 6.9 Hz, 6 H); TLC

conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (4:1); R_f = 0.62.

Step b:

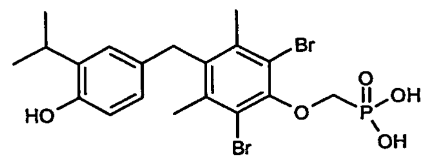
To a stirred solution of 2,6-diiodo-3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenol (0.2 g, 0.35 mmol) in DMF (3.0 mL) at 0 °C was added Cs_2CO_3 (0.34 g, 1.05 mmol). After 10-min, diethyl trifluoromethanesulfonyloxymethyl phosphonate (0.1 g, 0.35 mmol) was added. The reaction mixture was stirred at 0 °C for 1 h, allowed to warm to room temperature and stirred for 16 h. The reaction mixture was quenched with 1 N HCl, diluted with ethyl acetate, and washed with water (10 mLx4) and brine. The organic layer was concentrated under reduced pressure and the crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (2:3) as mobile phase to afford diethyl [2,6 diiodo-3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenoxy]methylphosphonate as an oil (0.21 g, 85%): ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.96 (d, J = 2.4 Hz, 1 H), 6.92 (d, J = 8.4 Hz, 1 H), 6.56 (dd, J = 2.1, 8.4 Hz, 1 H), 5.18 (s, 2 H), 4.45 - 4.35 (m, 6 H), 4.18 (s, 2H), 3.50 (s, 3H), 3.39 - 3.25 (m, 1 H), 2.49 (s, 6 H), 1.47 (t, J = 6.9 Hz, 6 H), 1.20 (d, J = 6.9 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (1:1); R_f = 0.35.

Step c:

To a solution of diethyl [2,6-diiodo-3,5-dimethyl-4-(3'-*iso*-propyl-4'-methoxymethoxybenzyl)phenoxy]methylphosphonate (0.14 g, 0.19 mmol) in CH_2Cl_2 (4.0 mL) at 0 °C was added bromotrimethylsilane (0.31 mL, 1.9 mmol). The reaction mixture was stirred at room temperature for 16 h and the solvent was removed under reduced pressure. The residue was treated with methanol and water (4:1, 5.0 mL) and the solvents were removed under reduced pressure. The residue was treated with acetonitrile and filtered to afford 2,6-diiodo-3,5-dimethyl-[4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methyl phosphonic acid as white solid (97 mg, 80%): mp 236 °C; ^{1}H NMR (300 MHz, CD_3OD): δ 6.87 (s, 1 H), 6.62 (d, J = 7.8 Hz, 1 H), 6.46 (d, J = 8.7 Hz, 1 H), 4.31 (d, J = 10.8 Hz, 2 H), 4.19 (s, 2 H), 3.35 - 3.18 (m, 1 H), 2.50 (s, 6 H), 1.17 (d, J = 6.9 Hz, 6 H); LC-MS m/z = 616 $[C_{19}H_{23}I_2O_5P]^+$; HPLC conditions: ODSAQ AQ-303-5 column; mobile phase = CH_3OH:0.05%TFA(7:3) flow rate = 1.0 mL/min; detection = UV @ 280 nm retention time in min: 13.82; Anal Calcd for ($C_{20}H_{25}O_6P$ + 0.9 H_2O): C, 36.09; H, 3.95. Found: C, 35.80; H, 4.22.

Using the appropriate starting material, compounds 65-2 was prepared in an analogous manner to that described for the synthesis of compound 65-1.

Compound 65-2: 2,6-dibromo-3,5-dimethyl-[4-(4'-hydroxy-3'-*iso*-propylbenzyl)phenoxy]methyl phosphonic acid



Step a

To a stirred solution of 3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol (0.2 g, 0.63 mmol), (G. Chiellini *et al. Bioorg. Med. Chem. Lett.* **2000**, *10*, 2607) in EtOH (6.0 mL) and CH_3NH_2 40% in water (2.5 mL) was added bromine (0.25 g, 1.59 mmol) and KBr (0.11 g 1.59 mmol) in H_2O (2 mL) at 0° C. The reaction mixture was stirred at room temperature for 16 h, quenched with water (50 mL) and extracted with ethyl acetate (50 mLx2). The combined organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with ethyl acetate-hexanes (1:9) to afford 2,6-dibromo-3,5-dimethyl-4-(4'-methoxymethoxy-3'-*iso*-propylbenzyl)phenol as a white solid (0.18 g, 60%): ^1H NMR (300 MHz, $CDCl_3$): δ 6.97 (d, J = 2.1 Hz, 1 H), 6.92 (d, J = 8.4 Hz, 1 H), 6.60 (dd, J = 2.4, 8.7 Hz, 1 H), 6.0 (s, 1 H), 5.19 (s, 2 H), 4.08 (s, 2 H), 3.50 (s, 3 H), 3.35 - 3.30 (m, 1 H), 2.38 (s, 6 H), 1.21 (d, J = 6.0 Hz, 6 H); TLC conditions: Uniplate silica gel, 250 microns; Mobile phase = hexanes-ethyl acetate (4:1); R_f = 0.62.

Step b:

The title compound was prepared according to the procedure described for the synthesis of example 45, step b and c as a white solid (0.15 g, 80%) mp 190 °C; ^1H NMR (300 MHz, CD_3OD): δ 6.88 (d, J = 2.1 Hz, 1 H), 6.62 (d, J = 8.4 Hz, 1 H), 6.46 (dd, J = 2.4, 8.7 Hz, 1 H), 4.27 (d, J = 10.5 Hz, 2 H), 4.12 (s, 2 H), 3.35 - 3.18 (m, 1 H), 2.40 (s, 6 H), 1.17 (d, J = 6.9 Hz, 6 H); LC-MS m/z = 523 $[C_{19}H_{23}I_2O_5P+H]^+$; HPLC conditions: ODSAQ AQ-12S05146W column; mobile phase = 0.05%TFA/CH_3CN:0.05%TFA/H_2O

(1:1) flow rate = 1.0 mL/min; detection = UV @ 254 nm retention time in min: 10.45; Anal Calcd for ($C_{20}H_{23}Br_2O_5P$): C, 43:70; H, 4.44. Found: C, 43.78; H, 4.46.

Example 66

Compound 66: 4,6-Dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)indolephosphonic acid

Step a:

A solution of sodium nitrite (155 mg, 2.24 mmol) in water (1 mL) was added to a suspension of 3,5-dimethyl-4-(4'-methoxy-3'-*iso*-propylphenoxy)-aniline (*J. Med. Chem.* **1995**, *38*, 695, 640 mg, 2.24 mmol) in ethanol (3mL) and concentrated hydrochloric acid (12 M, 1.12 mL, 13.44 mmol) at 0 °C. The yellow heterogeneous solution slowly turns to an orange clear solution. After stirring at 0 °C for 30 minutes, a solution of tin dichloride (1.53 g, 8.06 mmol) in hydrochloric acid (12 M, 1.3 mL, 15.68 mmol) was added. The orange solution turned green and a white precipitate formed. Ethanol (3 mL) was added to dissolve most of the precipitate and the heterogeneous reaction mixture was stirred at 0 °C. After 2 hours, water was added and the precipitate collected by filtration. The sticky solid was dissolved in ethyl acetate and washed with water, 1 N sodium hydroxide then brine. The organics were dried over sodium sulfate, concentrated under reduced pressure and the residue was purified by column chromatography (silica gel, dichloromethane/methanol 95/5 to 90/10) to give 3,5-dimethyl-4-(4'-methoxy-3'-*iso*-propylphenoxy)-phenyl hydrazine (305 mg, 45%): ^1H NMR (300 MHz, $CDCl_3$) δ 6.77 (d, J = 3.0 Hz, 1H), 6.67 (d, J = 9.0 Hz, 1H) 6.58 (s, 2H), 6.37 (dd, J = 9.0, 3.0 Hz, 1H), 3.77 (s, 3H), 3.27 (heptuplet, J = 6.9 Hz, 1H), 2.09 (s, 3H), 1.18 (d, J = 6.9 Hz, 6H); TLC conditions: Merck silica gel, 250 microns; Mobile phase = dichloromethane-methanol (9:1), R_f = 0.6.

Step b:

Diethyl acetylphosphonate (183 mg, 1.02 mmol) was added to a yellow solution of hydrazine in toluene at rt. After stirring 10 minutes at rt, polyphosphoric acid (PPA, 0.4 g) was added and the turbid reaction mixture was placed in an oil bath at 115 °C. After refluxing for 5 minutes, the cooled brown biphasic solution was partitioned between ethyl acetate and water and the organic layer was washed with water then brine, dried over sodium sulfate, concentrated under reduced pressure and the residue purified by column chromatography (silica gel, hexanes/ethyl acetate 70/30 to 20/80) to give diethyl 5,6-dimethyl-4-(4'-methoxy-3'-*iso*-propylphenoxy)indolephosphonate (276 mg,

61%): ^{1}H NMR (300 MHz, $CDCl_3$) δ (s, 1H, exchangeable with D_2O), 7.17 (s, 1H), 7.07 (m, 1H), 6.83 (d, J = 3.0 Hz, 1H), 6.65 (d, J = 9.0 Hz, 1H), 6.34 (dd, J = 9.0, 3.0 Hz, 1H), 4.30-4.08 (m, 4H), 3.77 (s, 3H), 3.28 (heptuplet, J = 6.9 Hz, 1H), 2.35 (s, 3H), 2.24 (s, 3H), 1.37 (t, J = 7.1 Hz, 6H), 1.18 (d, J = 6.9 Hz, 6H); TLC conditions: Merck silica gel, 250 microns; Mobile phase = dichloromethane-methanol (9:1); R_f = 0.55.

Step c:

5,6-Dimethyl-4-(4'-hydroxy-3'-*iso*-propylphenoxy)indolephosphonic acid was prepared according to the procedure described for the synthesis of example 8, step f (100 mg, 51%): ^{1}H NMR (300 MHz, CD_3OD) δ 7.14 (s, 1H), 6.97 (s, 1H), 6.75 (d, J = 9.0 Hz, 1H), 6.68 (d, J = 3.0 Hz, 1H), 6.35 (dd, J = 9.0, 3.0 Hz, 1H), 3.75 (s, 3H), 3.25 (heptuplet, J = 6.9 Hz, 1H), 2.27 (s, 3H), 2.16 (s, 3H), 1.11 (d, J = 6.9 Hz, 6H); LC-MS m/z = 390.4 $[C_{20}H_{24}NO_5P + H]^+$.

Step d:

A solution of boron tribromide (1 M in dichloromethane, 1.3 mL, 1.3 mmol) was added to a solution of 5,6-dimethyl-4-(4'-methoxy-3'-*iso*-propylphenoxy)indolephosphonic acid (100 mg, 0.26 mmol) in dichloromethane (10 mL) at -78 °C. The ice bath was removed and the reaction mixture was warmed to rt. After stirring at rt overnight, the reaction mixture was quenched with ice, diluted with ethyl acetate and washed with water then brine, dried over sodium sulfate and concentrated under reduced pressure to give the title compound (86.3 mg, 80%): ^{1}H NMR (300 MHz, CD_3OD) δ 7.18 (s, 1H), 6.97 (d, J = 3.0 Hz, 1H), 6.60 (s, 1H), 6.57 (d, J = 9.0 Hz, 1H), 6.26 (dd, J = 9.0, 3.0 Hz, 1H), 3.22 (heptuplet, J = 6.9 Hz, 1H), 2.28 (s, 3H), 2.18 (s, 3H), 1.12 (d, J = 6.9 Hz, 6H); Anal. Calcd for ($C_{19}H_{22}NO_5P$ + 1.5 H_2O + 0.1 C_3H_6O): C, 56.79; H, 6.32; N, 3.43. Found: C, 56.61; H, 5.92; N, 3.22.

Abbreviations:

CH_2Cl_2: dichloromethane

DMF: dimethylformamide

TEA: triethylamine

THF: tetrahydrofuran

TFA: trifluoroacetic acid

$MgSO_4$; magnesium sulfate

TBSCl: *t*-butyldimethylsilyl chloride

H_2O: water

DMSO: dimethyl sulfoxide

CH_3CN: acetonitrile

For the purposes of clarity and brevity compounds are referred to by compound numbers (from the Table below) in the biological examples below.

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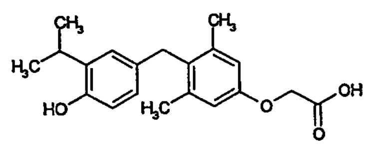
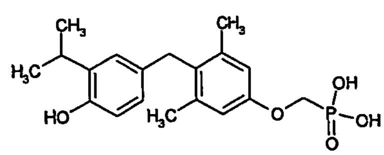
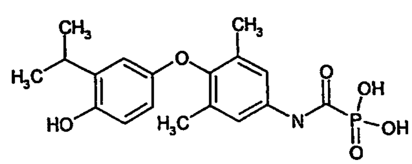
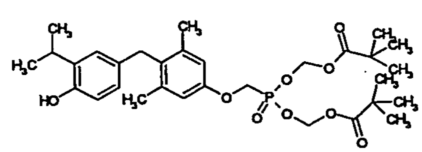
	17
	7
	1
	12-1

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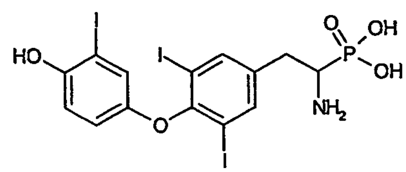
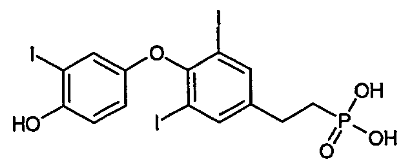
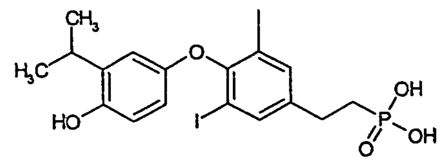
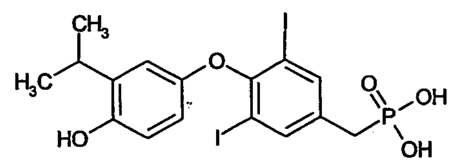
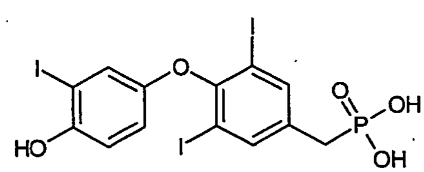
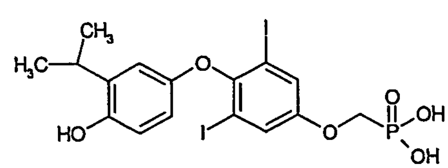
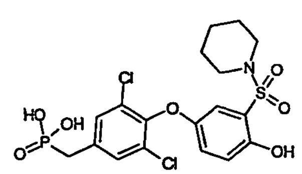
	2
	3
	4
	5
	6
	8
	9

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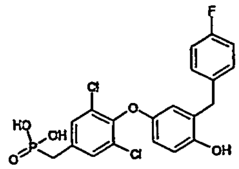
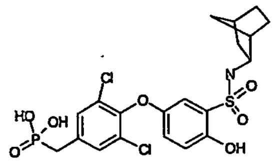
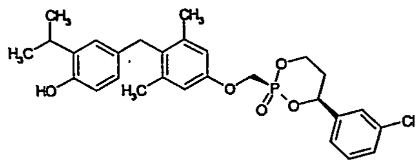
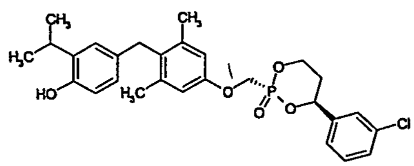
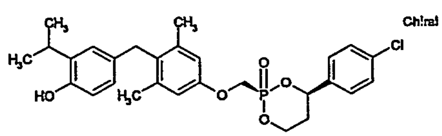
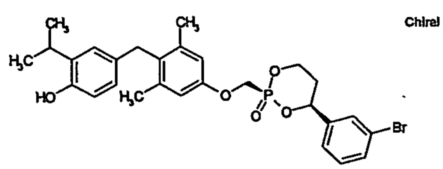
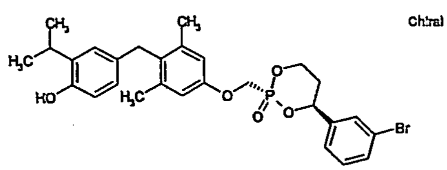
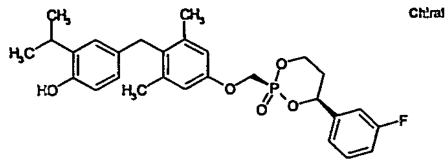
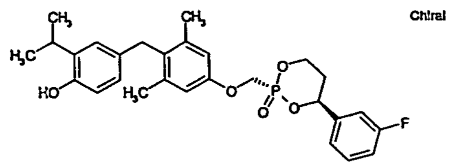
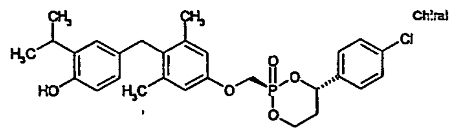
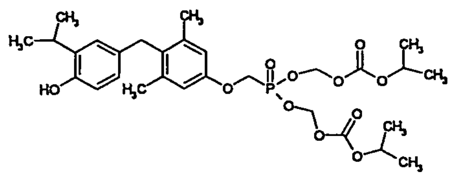
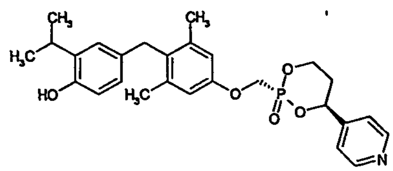
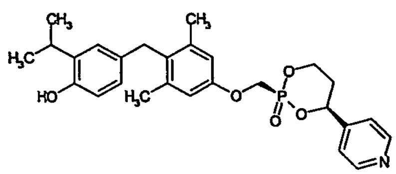
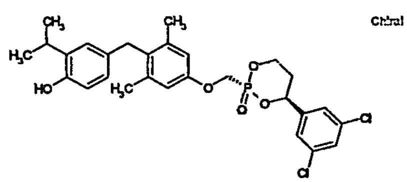
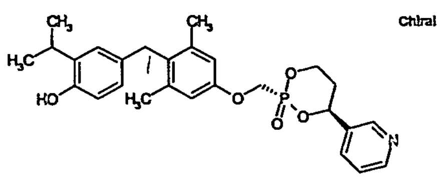
	11
	10
	*cis*-13-1
	*trans*-13-1
	*cis*-13-6
	*cis*-13-2
	*trans*-13-2

Structure	Compound Number
	*cis*-13-3
	*trans*-13-3
	*trans*-13-6
	12-3
	*trans*-13-5
	*cis*-13-5
	*trans*-13-7
	*trans*-13-4

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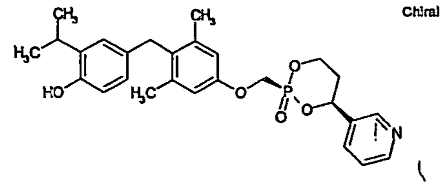
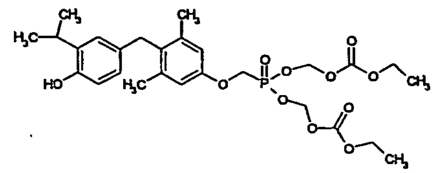
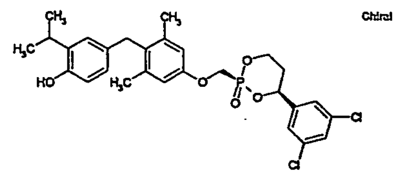
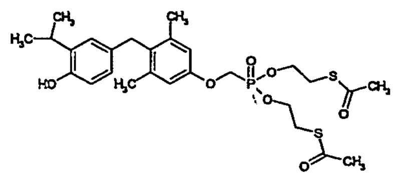
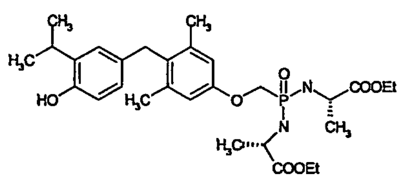
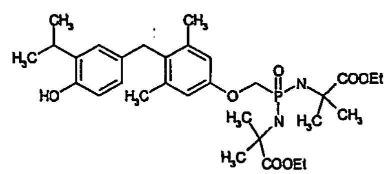
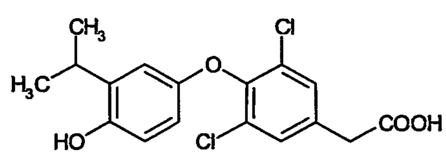
	*cis*-13-4
	12-2
	*cis*-13-7
	14
	15-1
	15-2
	18

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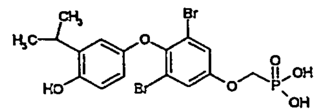
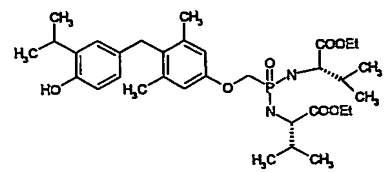
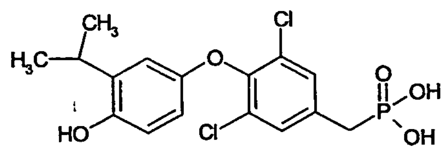
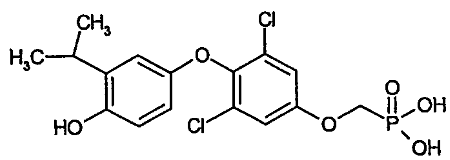
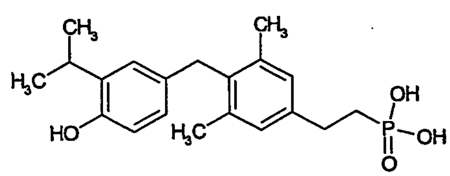
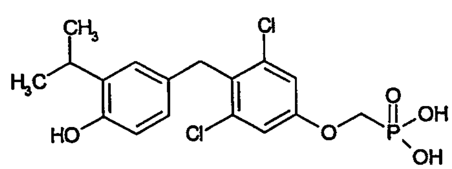
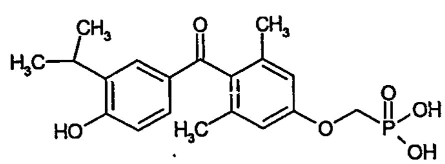
	8-1
	15-3
	19
	8-2
	24-1
	7-5
	25

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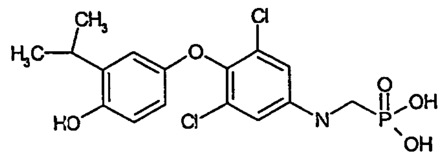
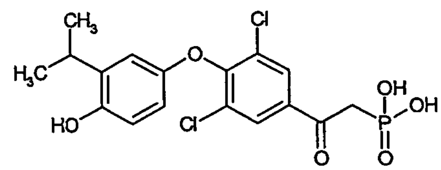
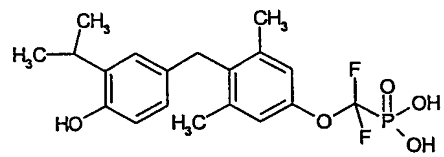
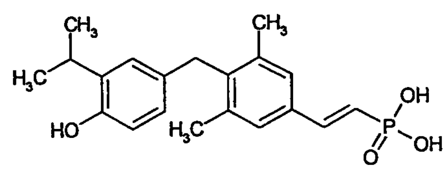
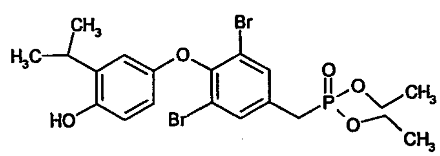
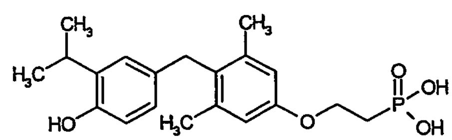
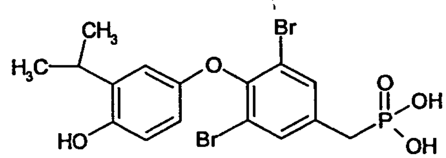
	22
	21
	7-6
	24-2
	19-1
	26
	19-2

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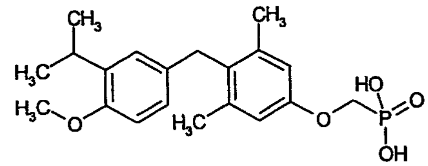
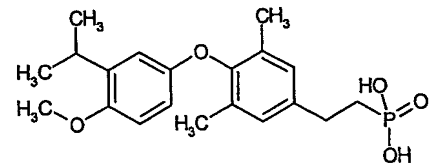
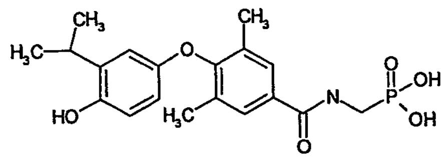
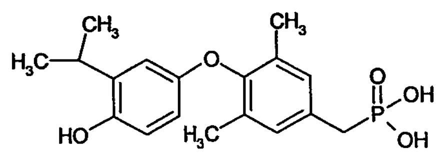
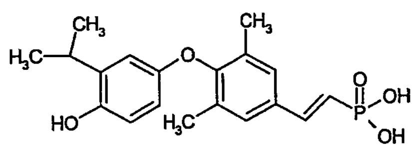
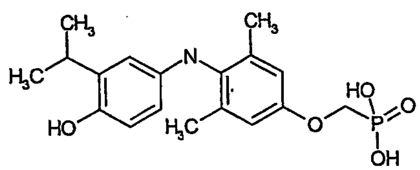
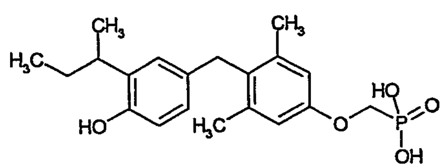
	7-4
	30
	23
	19-3
	28
	20
	7-3

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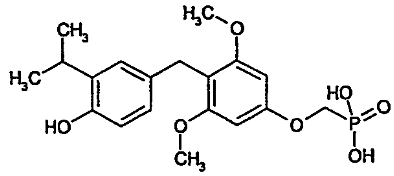
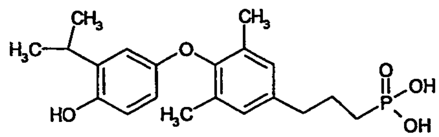
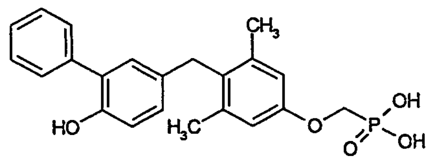
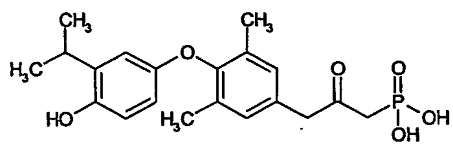
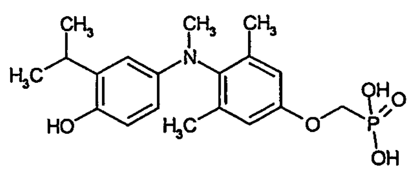
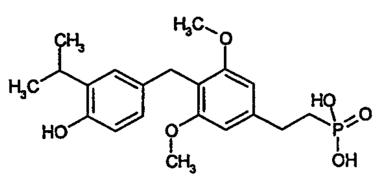
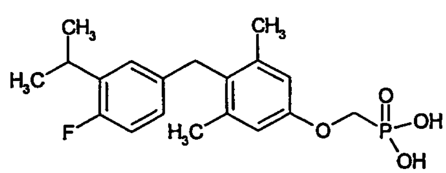
	7-2
	29
	7-1
	32
	20-1
	24
	27

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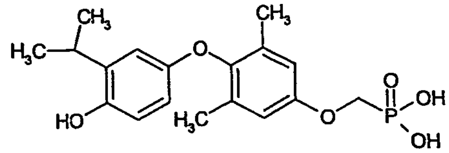
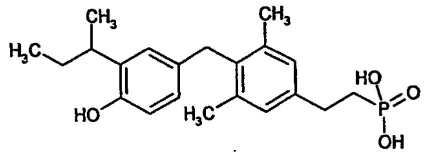
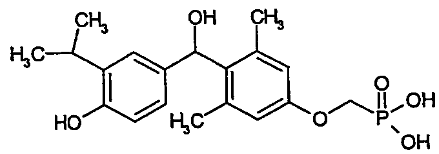
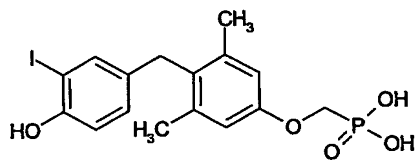
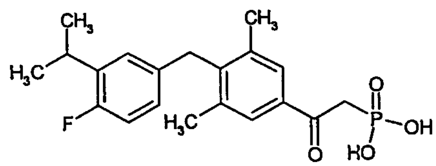
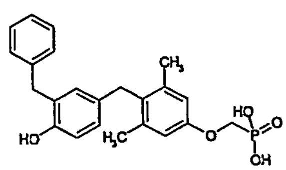
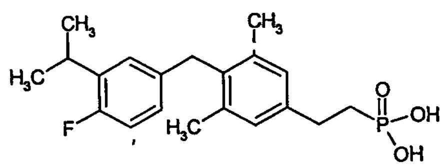
	31
	24-3
	33
	34
	41-2
	38
	42-2

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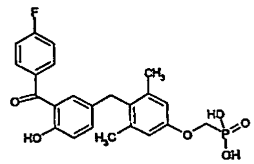
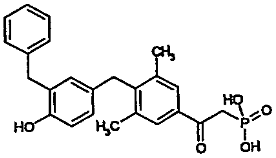
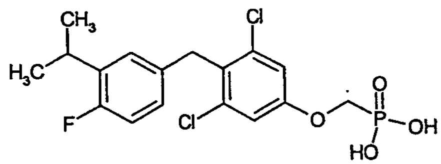
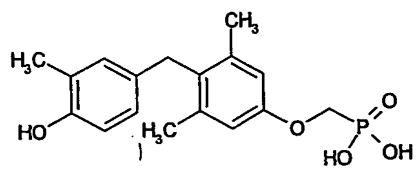
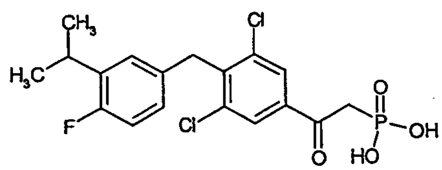
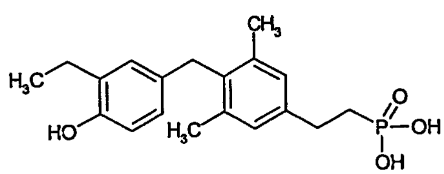
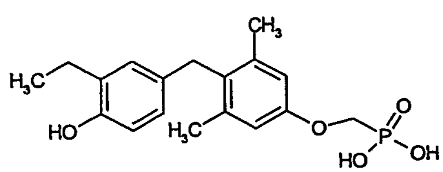
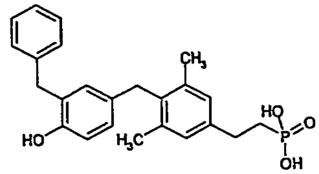
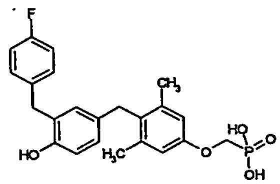
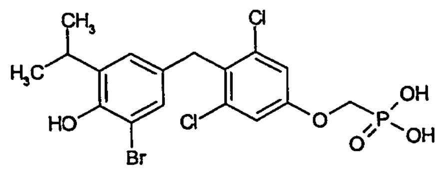
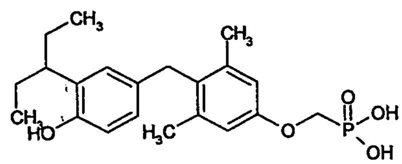
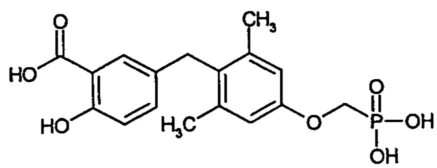
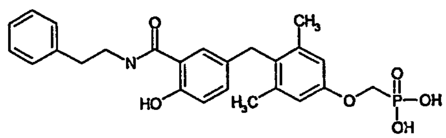
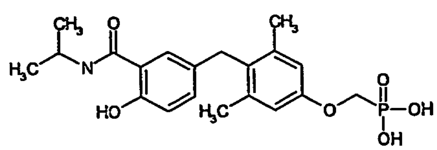
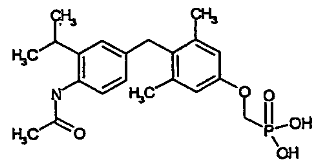
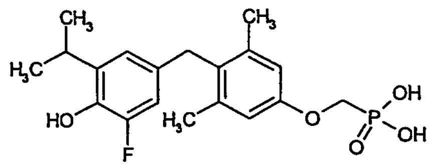
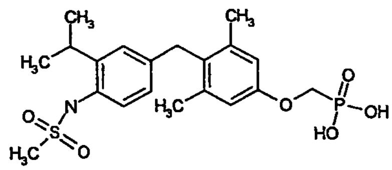
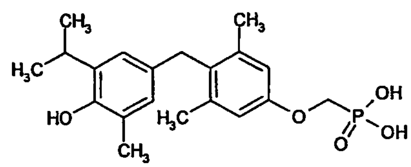
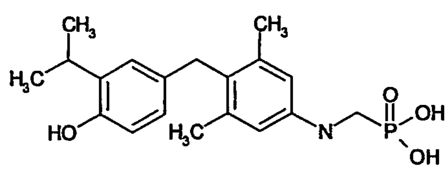
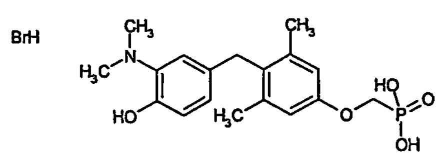
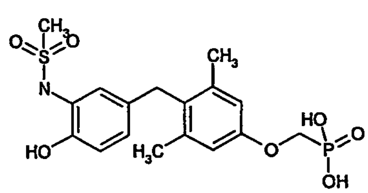
	39
	41
	27-2
	7-7
	41-3
	24-4
	7-8

Structure	Compound Number
	42
	40
	7-14
	7-9
	35
	37
	36

Structure	Compound Number
	7-12
	7-11
	7-13
	7-10
	47
	49
	51-1

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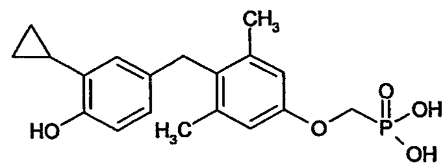
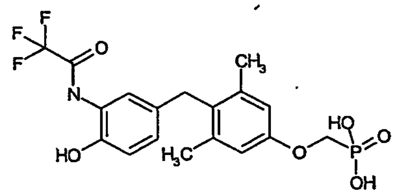
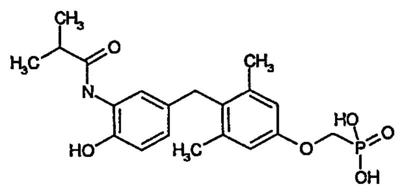
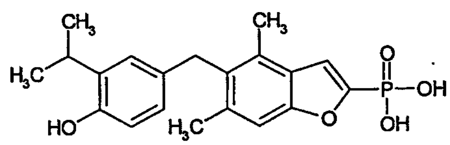
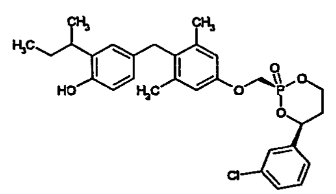
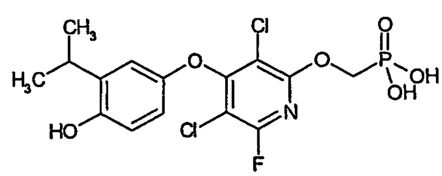
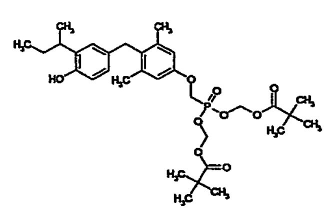
	48
	51-2
	51-3
	45
	13-8
	57
	12-4

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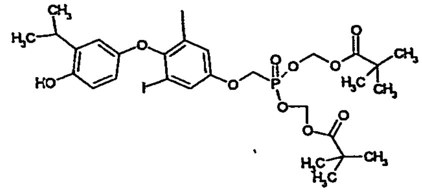
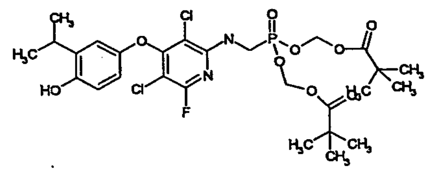
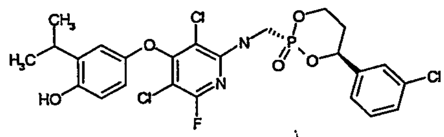
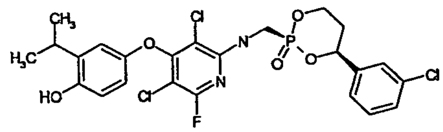
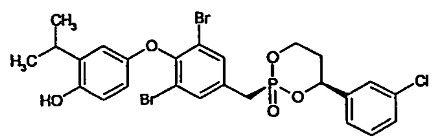
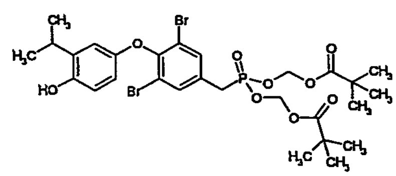
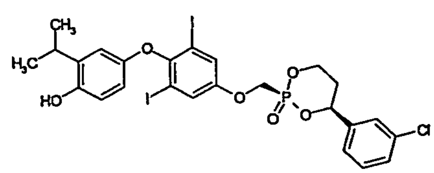
	12-7
	12-9
	13-12-*trans*
	13-12-*cis*
	13-9
	12-5
	13-10

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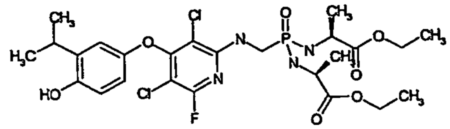
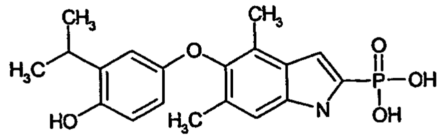
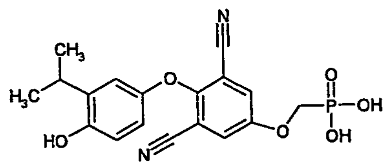
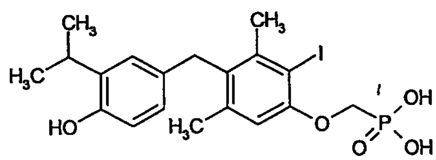
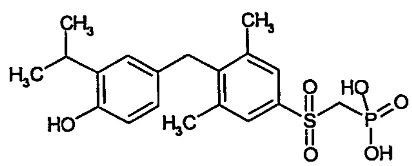
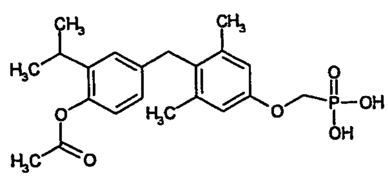
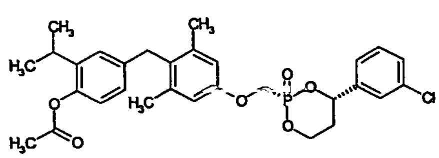
	15-6
	66
	56
	46
	52
	58
	59

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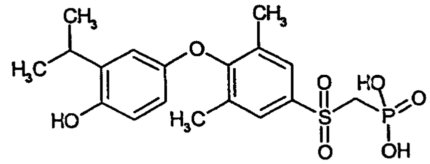
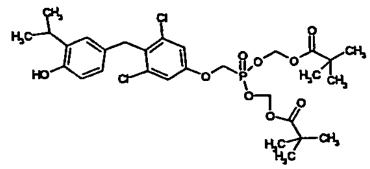
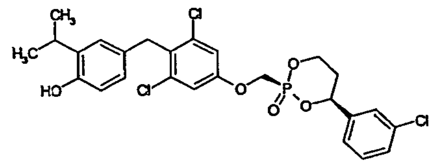
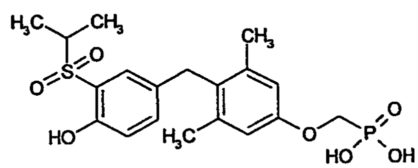
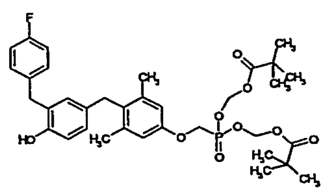
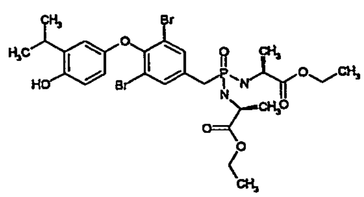
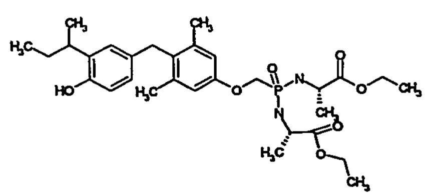
	53
	12-8
	13-11
	44
	12-6
	15-5
	15-4

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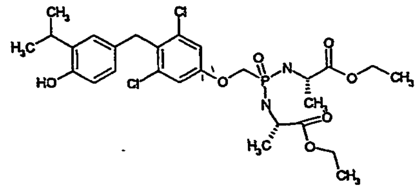
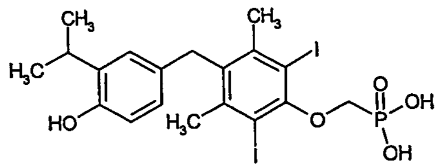
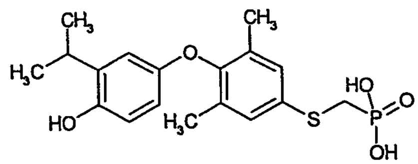
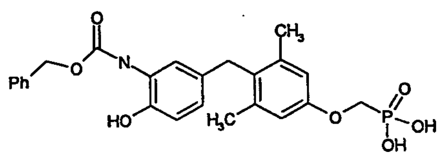
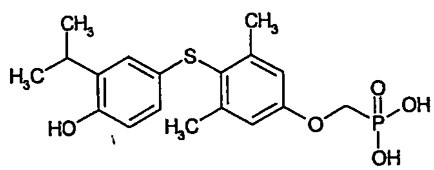
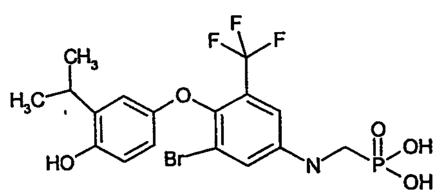
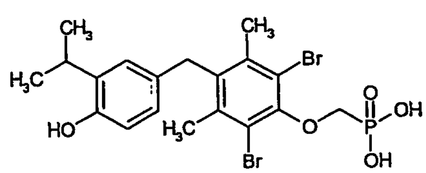
	15-7
	65-1
	54
	50
	43
	63
	65-2

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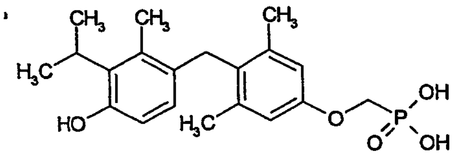
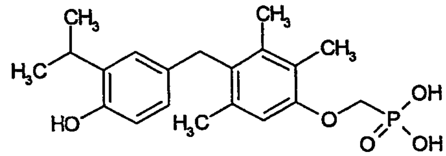
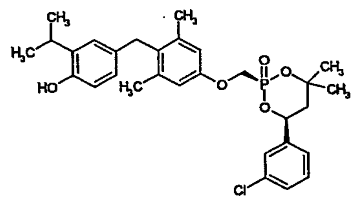
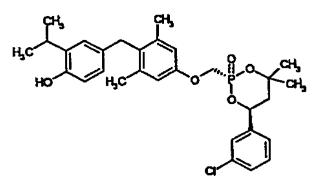
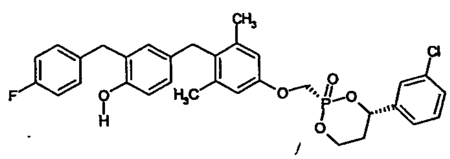
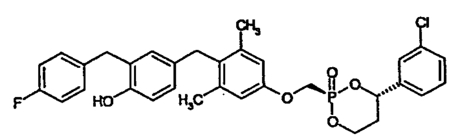
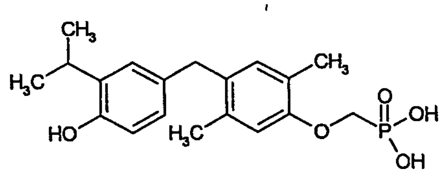
	7-16
	61
	13-13-*cis*
	13-13-*trans*
	13-14-*cis*
	13-14-*trans*
	7-17

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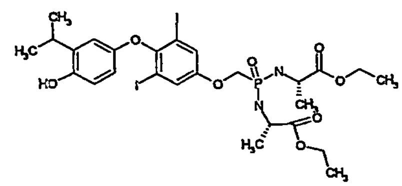
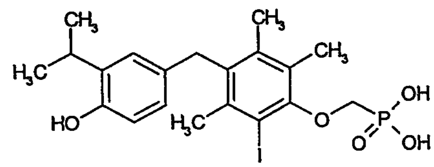
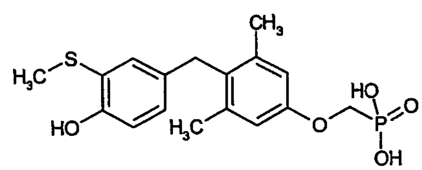
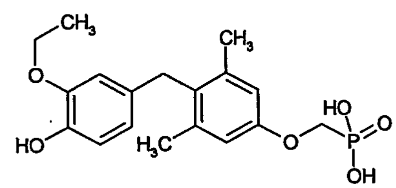
	15-8
	62
	55
	7-15

BIOLOGICAL EXAMPLES

Examples of use of the method of the invention includes the following. It will be understood that these examples are exemplary and that the method of the invention is not limited solely to these examples.

For the purposes of clarity and brevity, chemical compounds are referred to as synthetic example numbers in the biological examples below.

Example A: Receptor Binding

The purpose of these studies was to determine the affinity of T3 and various thyromimetics for human thyroid hormone receptors TRα1 and TRβ1.

Methods: Baculoviruses expressing TRα1, TRβ1 and RXRα were generated using cDNA and other reagents from Invitrogen (Carlsbad, CA). To produce TR/RXR

heterodimer proteins, the sf9 insect cells were first grown to a density of 1-5x10^5 cells/ mL. TRα1 or TRβ1 and RXRα baculovirus stocks were added to the cell culture with a ratio of 1 to 1 (multiplicity of infection =10). The cells were harvested three days after the infection. The cells were lysed in assay buffer (50 mM NaCl, 10% Glycerol, 20 mM tris, pH 7.6 2 mM EDTA, 5 mM β-mercaptoethanol and 1.25% CHAPS) and the lysates were assayed for T3 binding as follows: ^{125}I-T3 was incubated with the lysates of TR and RXR recombinant baculoviruses coinfected cells (50 μl) in assay buffer for one h and then the ^{125}I-T3-TR/RXR complex was separated from free ^{125}I-T3 by a mini-gel-filtration (Sephadex G50) column. The bound ^{125}I-T3 was counted with a scintillation counter.

Binding of compounds to either the TRα1 or TRβ1 were also performed by means of scintillation proximity assays (SPA). The SPA assay, a common method used for the quantitation of receptor-ligand equilibria, makes use of special beads coated with a scintillant and a capture molecule, copper, which binds to the histidine-tagged α or β receptor. When labeled T3 is mixed with receptor and the SPA beads, radioactive counts are observed only when the complex of protein and radiolabeled ligand is captured on the surface of the bead. Displacement curves were also generated with labeled T3 and increasing concentrations of unlabeled thyromimetics of interest .

Results: Examples of representative T3 binding results using the gel filtration method are shown in Figure 1(a). SPA assay results for T3 are shown in Figures 1(b) and 1(c). Table 3 below shows the SPA data generated with various thyromimetics of interest. Binding results for T3 demonstrated a Kd=0.29nM for TRα and a Kd=0.67nM for TRβ.

TABLE 3

Compound	Ki TRα (nM)	Ki TRβ (nM)
17	1.21	0.29
1	285	36.1
12-1	1666	662
3	46	5.42
6	16	26
9	350	204
11	121	30.3
13-1-*cis*	2583	1979
13-1-*trans*	1744	1322
13-6-*cis*	4710	3589
13-2-*cis*	488	419
13-2-*trans*	1354	469
13-3-*cis*	2837	3431

Compound	Ki TRα (nM)	Ki TRβ (nM)
13-3-*trans*	2006	2456
13-6-*trans*	1526	1574
13-5-*trans*	354	281
13-5-*cis*	4432	1008
13-7-*trans*	1554	3798
13-4-*trans*	2129	1815
13-4-*cis*	5531	1521
13-7-*cis*	49632	45135
7	58	3.3
2	1416	271
4	14.1	0.99
5	1.84	0.84
8	3.74	0.97
10	>2000	>2000
8-1	18.6	2.51
15-3	>2000	>2000
19	304	52
8-2	114	20
24-1	378	31
7-5	67	9.5
25	>2000	363
22	186	31
21	>1400	>180
7-6	98	7.6
24-2	>2000	24
26	594	87
19-2	343	20
7-4	>2000	>2000
30	>2000	>2000
23	>2000	>2000
19-3	1760	128
28	375	14.0
20	>2000	>2000
7-3	31	6.6
7-2	>2000	146
29	661	47
7-1	1166	106
32	284	96
24	>2000	>2000
27	>2000	>2000
31	540	73
24-3	113	2.87
33	267	16.7
34	118	6.5
41-2	>2000	>2000
38	254	5.4
42-2	>2000	>2000
39	>2000	58
7-7	898	90
41-3	>2000	280

Compound	Ki TRα (nM)	Ki TRβ (nM)
24-4	>2000	92
7-8	62	9.7
42	794	16.2
40	30	1.1
7-14	429	52
7-9	110	5.4
35	>2000	>2000
37	294	23
36	>2000	106
7-12	>2000	61
12-3	738	156
41	>2000	181
7-10	112	48
47	24.3	2.5
48	128.6	9
45	216	14
46	20	2
52	>2000	48
44	832	44
54	143	42
43	363	108

Conclusion: The parent thyromimetics tested had good to excellent affinity for the TRα1 and/or TRβ1 receptors. The prodrugs had poor affinity for the receptors and are therefore unlikely to exert a thyromimetic effect until activated in the liver.

Example B: Subacute Studies in Normal Mice/Rats Demonstrating Liver versus Heart Selectivity of Phosphonic Acid and Carboxylic Acid T3 Mimetics.

The purpose of these studies was to compare the difference in efficacy, cardiac effects and endocrine effects between T3 and T3 mimetics that are carboxylic acids and T3 mimetics that are phosphonic acids. In one example, T3 and Compounds 7 and 17, which differ only in that for Compound 7 X is -P(O)OH_2 and for Compound 17 X is -C(O)OH, were compared. Efficacy endpoints include serum cholesterol, liver mitochondrial glycerol phosphate dehydrogenase (mGPDH) activity and the expression of relevant liver genes (*e.g.*, the LDL-receptor, apoB, cpt-1, spot14 and apoAI). Safety parameters include heart weight, heart rate, heart mGPDH activity, the expression and key genes involved in cardiac structure and function (*e.g.*, Serca2, HCN2,Kv1.5, MHCα, MHCβ, Alpha1c), and standard plasma chemistry analysis (liver enzymes, electrolytes, creatinine). Endocrine effects are monitored by analysis of serum thyroid stimulating

hormone (TSH). [Taylor *et al., Mol Pharmacol* 52(3): 542-7 (1997); Weitzel *et al., Eur J Biochem* 268(14):4095-4103 (2001)]

Methods: mGPDH activity was analyzed in isolated mitochondria using 2-(4-iodophenyl)-3-(4-nitrophenyl)-5-phenyl tetrazolium chloride as the terminal electron acceptor (Gardner RS, Analytical Biochemistry 59:272 (1974)). Commercially available GPDH was used in each assay as a standard (Sigma, St. Louis, MO). Changes in levels of mRNA for liver and heart genes are analyzed using reverse transcriptase followed by real-time PCR analysis. The analysis is performed using an iCycler instrument (Biorad) and appropriate primers by means of standard methodology [*e.g.*, Schwab DA *et al.* (2000) *Life Sciences* 66: 1683-94]. The amounts of mRNA are normalized to an internal control, typically, cyclophilin. Serum TSH is measured using an enzyme immunoassay (EIA) kit designed for rat TSH (Amersham Pharmacia Biotech, Arlington Heights, IL). Serum cholesterol is analyzed using a commercially available enzymatic kit (Sigma Diagnostics, St. Louis, MO).

Normal rats (Sprague-Dawley) were maintained on a standard diet. Compounds 7 and 17, or T3 were administered by continuous infusion using an osmotic pump (Alzet; subcutaneous implant) at a dose of 1 mg/kg/day. The compounds were dissolved in 0.1N NaOH solution and the pH adjusted to 7.4-8.0. The compounds were brought up to an appropriate volume using PBS and BSA to maintain solubility within the pump. The compounds were chemically stable in the excipient at 37 °C for 7 days.

Results: Compound 7, a phosphonic acid T3 mimetic, produced a significant thyromimetic effect in the liver equivalent to that of T3 or Compound 17, a carboxylic acid T3 mimetic, without producing any signficant effect in the heart. Compound 17 produced a significant thyromimetic effect comparable to that of T3 in both organs. Values are expressed as percent of control. (Table 4)

TABLE 4

	Liver GPDH	Heart GPDH	Heart Weight
control	100	100	100
T3	406	284	146
Compound 17	426	277	134
Compound 7	399	112	108

Conclusion: Based on mGPDH enzyme activity, Compound 7 had significant thyromimetic activity in the liver and none in the heart. In addition, Compound 7 did not

cause cardiac hypertrophy. T3 and Compound 17, in contrast, did not show liver-selective thyromimetic effects. Thus, the results demonstrate that phosphonic acid T3 mimetics have a greater selectivity for the heart in terms of drug activity and distribution than carboxylic acid T3 mimetics.

Example C: Subacute Studies in ZDF Rats Demonstrating Improved Therapeutic Index for Phosphonic Acid Containing T3 Mimetics

ZDF rats were treated with either Compound 18 (a carboxylic acid T3 memitic) or Compound cis-13-1 (a HepDirect prodrug of a phosphonic acid T3 memitic) for 28 days dosed orally once a day. Compound 18 was administered at doses up to 5 mg/kg/d. Compound *cis*-13-1 was administered at doses up to 50 mg/kg/d. We reasoned that the ZDF rat, as a metabolically challenged animal model, would be more sensitive to the potential adverse cardiac effects of thyromimetics than a normal, cholesterol-fed rat. At sacrifice, heart rate, and the first derivative of left ventricular pressure (LV dP/dt) were measured with a Millar catheter inserted into the left ventricle. The therapeutic index (TI) for Compound 18 in the cholesterol-fed rat was 40 with respect to heart rate increases (Grover *et al.* PNAS 2003). The measurement of TI was a dose that ED15 for heart rate, *i.e.*, a dose that increased heart rate greater than or equal to 15% compared to the ED50 for cholesterol lowering. The therapeutic index for Compound 18 in the ZDF rats with respect to heart rate was 0.4, indicating that the model is much more sensitive to cardiac effects than a non-metabolically challenged animal. Additionally, the TI for LV dP/dt was 0.15. An increase in LV dP/dt of 25% was the value used in the TI calculation. The most sensitive measure of cardiac effects in this animal was LV dP/dt. ZDF rats treated with Compound cis-13-1 showed no changes in any of the parameters measured. Since we only dosed up to 50 mg/kg/d, we do not know the exact therapeutic index for some of these parameters. However, the TI improvement over Compound 18 is listed in the table below:

Parameter	TI Improvement
ED15 HR	>39
ED25 LV dP/dt	>102

The reason that the TI is listed as greater than, *i.e.*, ">" is that the doses of Compound *cis*-13-1 were not high enough to reach the 15% or 25% threshold even at 50

mg/kg/d. By extrapolation with the cholesterol-fed rat for the Compound 18 data, the ZDF rats were 100-times more sensitive to the cardiac effects of the compound (a TI of ED15 HR/ED50 cholesterol from 40 in the normal rat to 0.4 in the ZDF rat). Therefore we calculate that the TI in a non-metabolically challenged animal would be >3900 with respect to heart rate and >10,000 with respect to LV dP/dt. We chose not to dose at such high levels at this time since the results from the ZDF animals demonstrated a significantly improved safety window. Thus the compounds of the present invention demonstrate a TI that is unexpected and vastly superior than carboxylic acid T3 mimetics.

Example D: Subacute Studies in Cholesterol-fed Rats

The cholesterol-fed rat is an animal model of hypercholesterolemia generated by feeding the animals a diet with high cholesterol content. The purpose of these studies was to evaluate the effects of Compounds 7 and 17 on serum cholesterol (an efficacy parameter) and on heart weight and heart mGPDH activity (potential toxicity parameters).

Methods: Rats were maintained on a diet containing 1.5% cholesterol and 0.5% cholic acid for 2 weeks prior to initiation of treatment. Serum cholesterol values were assessed and the animals randomized into groups for treatment. Serum cholesterol was analyzed using a commercially available enzymatic kit (Sigma Diagnostics, St. Louis, MO). Compound 17 and Compound 7 at various concentrations were administered IP once-a-day for seven days.

Results: Doses of 0.1-1 mg/kg/day Compound 17 significantly decreased serum cholesterol. Doses of Compound 7 from 1-100 mg/kd/day significantly decreased serum cholesterol. The decreases of serum cholesterol at 1 mg/kg/day were identical for Compound 17 and Compound 7 (*see* Fig. 2). Undesirable cardiac hypertrophy was observed with Compound 17 at all doses which significantly decreased serum cholesterol, 0.1-1 mg/kg/day. No cardiac hypertrophy was observed with Compound 7 (*see* Fig. 3). Cardiac GPDH activity was also increased by Compound 17 at 1 mg/kg/day whereas a trend towards increased heart GPDH activity was observed with compound 7 only at 100 mg/kg (*see* Fig. 4). No adverse cardiac effects were observed with Compound 7 at any dose. These studies also indicate that cardiac weight is more sensitive to thyromimetic effects than GPDH activity.

Conclusion: There is no separation between efficacy (cholesterol lowering) and toxicity (cardiac hypertrophy, induction of heart GPDH) for compound 17. Compound 7, in contrast, showed a therapeutic window of 10- to 100-fold. Thus, the results demonstrate that phosphonic acid T3 mimetics have a greater therapeutic window than carboxylic acid T3 mimetics.

Example E: Microsome/Primary Hepatocyte Stability Studies

i. Prodrug activation in Rat Liver Microsomes

The purpose of these studies was to determine the kinetics of activation of prodrugs of thyromimetics in microsomal preparations. Microsomes contain the P450 enzyme that is required for the activation of many of the prodrugs prepared. The Km, Vmax, and intrinsic clearance values determined are measures of prodrug affinity for the microsomal enzymes, the rate at which the prodrug is activated, and the catalytic efficiency with which the prodrug is activated, respectively.

Methods: Activation of prodrugs by dexamethasone treated rat hepatocyte microsomes. Microsomes were isolated by standard differential centrifugation methods from dexamethasone-treated rats. The treatment is to increase cytochrome P450-3A (CYP3A4) activity. Induction of CYP3A4 was confirmed by an increase in testosterone hydroxylation.

Various concentrations of HepDirect™ Compound 7 were incubated with rat hepatocytes microsomes. Compound 7 formation was analyzed by HPLC using UV-Vis detection. Kinetic parameters (V_{max} and K_m) were calculated from the transformed data and the intrinsic clearance calculated from the kinetic parameters.

Results and conclusion: Table 5 shows that prodrugs of Compound 7 are well activated in rat liver microsomes and have good affinity for the microsomal enzyme(s) catalyzing their activation:

TABLE 5

Compound	Vmax (pmol/min/mg)	Km (µM)	CLint (µL/min/mg)
13-1-*cis*	1746	31	56
13-6-*cis*	598	10	62
13-2-*cis*	694	8	86
13-3-*cis*	2118	46	46
13-5-*cis*	3266	113	29
Compound 12-3	775	14	54
13-4-*cis*	2983	100	30

ii. <u>Activation of Prodrug by Human Liver S9</u>

Prodrugs are tested for conversion to their respective parent compounds by human liver S9. The S9 fraction is a fraction that contains both cytosolic and microsomal protein..

Method: Reaction mixtures (0.5 mL at 37 °C) consist of 0.2 M potassium phosphate pH 7.4, 13 mM glucose-6-phosphate, 2.2 mM $NADP^+$, 1 unit of glucose-6-phosphate dehydrogenase, 0-2.5 mg/mL human liver S9 fraction (In Vitro Technologies, Inc.), and up to 250 µM of prodrug. The activation of the prodrugs to the respective parent compounds is monitored by reverse phase HPLC or LC-MS/MS (Example F).

Results: The rate of formation of the parent compound is measured. The enzyme kinetic parameters of V_{max}, K_m, and intrinsic clearance CL_{int} are calculated.

Conclusion: Prodrugs of T3 mimetics are readily activated to their respective parent compound by human liver S9.

iii. <u>Activation of Prodrug in Isolated Rat Hepatocytes</u>

The purpose of these studies was to monitor the uptake and activation of the prodrugs of T3 mimetics to their respective active species in fresh, isolated rat hepatocytes.

Method: Hepatocytes are prepared from fed Sprague-Dawley rats (250-300 g) according to the procedure of Berry and Friend (Berry, M. N., Friend, D. S. *J. Cell Biol.* 43, 506-520 (1969)) as modified by Groen (Groen, A. K. *et al., Eur J. Biochem* 122, 87-93 (1982)). Hepatocytes (60 mg wet weight/ mL) are incubated in 1 mL Krebs-bicarbonate buffer containing 10 mM glucose, and 1 mg/ mL BSA. Incubations are carried out in a 95% oxygen, 5% carbon dioxide atmosphere in closed, 50-mL Falcon

tubes submerged in a rapidly shaking water bath (37 °C.). Prodrugs are dissolved in DMSO to yield 10 mM stock solutions, and then diluted into the cell suspension to yield a final concentration of 100 μM. At appropriate time points over the course of 1 h, aliquots of the cell suspension are removed and spun through a silicon/mineral oil layer into 10% perchloric acid. The cell extracts in the acid layers are neutralized, and the intracellular prodrug metabolite content analyzed by reverse phase HPLC or LC-MS/MS (Example F). The AUC of the active species in the hepatocytes is calculated from the concentration-time profile of parent compound.

Results: Results are shown in Table 6 below:

TABLE 6

Compound	AUC (0-2h) (nmole*h/g)
Compound 7	1371
Compound 13-1-*cis*	967
Compound 13-6-*cis*	433
Compound 13-2-*cis*	533
Compound 3-3-*cis*	459
Compound 13-5-*cis*	1988
Compound-13-7-*cis*	806
Compound 13-4-*cis*	784

Conclusion: Prodrugs of T3 mimetics are readily taken up and activated to their active species in fresh rat hepatocytes.

Example F: Oral Bioavailability/Efficacy Studies in Normal Rats

i. Oral Bioavailability

The oral bioavailability (OBAV) of Compound 12-1, a bisPOM prodrug of Compound 7,was estimated by comparison of the dose-normalized area under the curve (AUC) of the plasma concentration-time profile of Compound 7 following IV and PO administration of Compound 7 and Compound 12-1, respectively, to normal rats.

Method: Groups of non-fasted male SD rats were administered either 5 mg/kg of Compound 7 by IV bolus or 20 mg/kg of Compound 12-1 by oral gavage. Prior to drug administration, the rats were catheterized at the tail artery to facilitate blood collection. Plasma samples were obtained at pre-specified time points following dosing, extracted with 1.5 volumes of methanol, and then assayed by an LC-UV method using a C18 column eluted with a gradient of 20% to 45% v/v acetonitrile in a potassium phosphate buffer pH 6.2 over 15 min with UV absorbance monitoring at 280 nm. The AUC values

were determined noncompartmentally from the plasma concentration-time plots by trapezoidal summation to the last measurable time point.

In another experiment the OBAV of Compound 19-2, a phonsphonic acid T3 mimetic, was assessed using catheterized rats. Plasma levels of compound were analyzed by HPLC and the AUCs for the i.v. dose of 5 mg/kg and the p.o. dose of 20 mg/kg were compared. The maximum OBAV for Compound 19-2 was 0.003%. Typically, compounds that are taken forward as an oral drug candidate have OBAV values of at least 15-20%, when tested in an animal model. This minimal requirement for OBAV in a genetically homogenous model system insures that exposure can be accurately monitored when humans are treated with the compound. Furthermore, in a genetically variable background such as humans, the variability for a compound with low OBAV in genetically homogenous model systems, can be widely variable, leading some subjects to have much higher than anticipated exposure, while other subjects have no exposure. OBAV of Compound *cis*-13-1 is calculated to be 25% when AUC's of Compound cis-13-1 are used and to be 40-50% when comparing the AUC's of Compound 7 using serial plasma samples of a i.v. administered compound versus a p.o. administered compound. The liver levels at 1.5h post-dosing of Compound 7 and prodrugs thereof are listed in Table 7, example F (ii).

Results: Compound 12-1 was adequately absorbed in the rat with an estimated OBAV of 25%. Following oral administration of the prodrug, the plasma concentrations of the generated Compound 7 ($C_{max} = 1.2 \pm 0.2$ µg/mL at a $T_{max} = 3 \pm 1$ hr) were sustained over an 8 h period ($t_{1/2} = 6 \pm 6$ hr). Compound 19-2 was not adequately absorbed.

Conclusion: Adequate systemic exposure of Compound 7 was maintained over 8 h after an oral administration of Compound 12-1 to rats.

ii. <u>Liver Distribution Following Oral Administration</u>

Liver levels of Compound 7 were assessed in normal rats following oral administration of the HepDirect™ or other prodrugs. The levels were used to estimate potential efficacy. Liver levels were assessed by LC-MS using the 363.3/63.0 peak area to estimate levels of Compound 7 generated by orally administered prodrugs.

Results: Results are shown in Table 7.

TABLE 7

Compound	Liver Levels (ug/g) (10 mg/kg@1.5h)
Compound 7	Not Detected
Compound 12-1	1.39
Compound 13-1-*cis*	0.98
Compound 13-6-*cis*	0.39
Compound 13-2-*cis*	0.25
Compound 13-3-*cis*	0.77
Compound 12-2	0.67
Compound 13-5-*cis*	0.56
Compound 13-7-*cis*	0.23
Compound 13-4-*cis*	0.32

Conclusion: All compounds tested produced adequate liver levels of compound 7. All are predicted to induce thyromimetic effects *in vivo* following oral administration.

Example G: Oxygen Consumption Study

Thermogenesis is a measurement of energy consumption. Compounds that increase thermogenesis are likely to increase caloric expenditure and thereby cause body weight loss and its associated benefits to metabolic status (*e.g.*, insulin sensitivity). Thermogenesis is assessed in subcellular fractions of various tissues, isolated cells, whole tissues, or in whole animals using changes in oxygen consumption as the endpoint. Oxygen is used up when calories are burned by various metabolic processes.

Methods: Animals are dosed once or several times a day via a parenteral or oral route for a treatment period ranging from 1 day to several weeks. Oxygen consumption is measured following a single or multiple days of treatment.

Mitochondrial thermogenesis is measured polargraphically with a Clark-type oxygen electrode using mitochondria isolated from various tissues, including liver. Mitochondria are isolated by differential centrifugation. As those skilled in the art are familiar, state 3 respiration or cytochrome c oxidase activity are measured in isolated mitochondria. The mitochondria are incubated at 30 °C in a buffered medium containing

80 mM KCl, 50 mM HEPES, 5 mM KH2PO4, 1 mM EGTA, 0.1% (w/v) fatty acid-free bovine serum albumin (BSA), pH 7.0 in the presence of 10 mM succinate, 3/75 μM rotenone and 0.3 mM ADP (Iossa, S, *FEBS Letters*, 544: 133-7 (2003)).

Oxygen consumption rates are measured in isolated hepatocytes using a portable Clark-type oxygen electrode placed in the hepatocyte medium. Hepatocytes are isolated from liver using a two-step collagenase perfusion (Berry, M. N., Friend, D. S. *J. Cell Biol.* 43: 506-520 (1969)) as modified by Groen (Groen, A. K. *et al., Eur J. Biochem* 122: 87-93 (1982)). Non parenchymal cells are removed using a Percoll gradient and the cells are resuspended in tissue culture medium in a spinner flask. The oxygen consumption of the cells is measured over time once the system is sealed.

Oxygen consumption is measured in isolated perfused liver (Fernandez, V., *Toxicol Lett.* 69:205-10(1993)). Liver is perfused *in situ* and oxygen consumption is calculated by measuring the difference between the oxygen saturation of the inflow buffer and the outflow buffer maintained at a constant flow.

In one assay, whole animal oxygen consumption is measured using an indirect calorimeter (Oxymax, Columbus Instruments, Columbus, OH). Animals are removed from their cages and placed in the chambers. The resting oxygen consumption is measured in animals during periods of inactivity as measured by activity monitors. The oxygen consumption is calculated based on the flow through the chamber and the difference in oxygen partial pressures at the inflow and outlet ports. Carbon dioxide (CO_2) efflux is also measured in parallel using a CO_2 electrode.

Male Sprague Dawley rats were treated with 3, 10, or 30 mg/kg/d of Compound cis-13-1 orally for 14 days. Rats were placed in the FoxBox apparatus (Sable Sytems, Las Vegas, NV), allowed to acclimate and the resting oxygen consumption was measured. The oxygen consumption rates were compaired to pre-dose measurements taken on each individual animal. Oxygen consumption following treatment was 116, 125, 132% of the pre-dose rate, for 3, 10, and 30, respectively. Thus, the compounds of the present invention are useful in increasing oxygen consumption.

Example H: Tissue Distribution Studies

The tissue distribution and the pharmacokinetics of Compound 7 and the Compound 17 were assessed following IP administration to normal rats.

Method: In separate studies, the T3 mimetic phosphonate Compound 7 and its carboxylate analog Compound 17 were administered at 10 mg/kg to groups of male SD

rats via the tail vein under light isofluorane anesthesia. At pre-selected time points following dosing, the rats were re-anesthetized and the peritoneal cavity was then opened and a blood sample was obtained from the abdominal vena cava. In addition, liver, kidney, and heart were excised and immersed in 3 volumes of cold 60% acetonitrile. The blood samples were briefly centrifuged and the plasma fraction was then extracted with 1.5 volumes of methanol, processed, and analyzed by LC-UV as described in Example G. The frozen liver, kidney, and heart tissue were homogenized in 60% v/v acetonitrile, centrifuged, and then analyzed by LC-UV. Pharmacokinetic parameters and AUC of the plasma and tissue concentration-time profiles were determined noncompartmentally by WinNonLin.

Results: The following plasma pharmacokinetics were calculated for Compound 17 and Compound 7 and shown in Table 8.

TABLE 8

PARAMETER	UNIT	Compound 17	Compound 7
Dosing_time	hr	0	0
Rsq		0.9966	0.9893
Tmax	hr	0.3333	0.3333
Cmax	µg/mL	3.49	25.97
Tlast	hr	2	4
Vz(observed)/F	L/kg	2.2049	0.4008
Cl(observed)/F	L/hr/kg	3.3628	0.3006
AUMClast	µg*hr^2/mL	1.7683	33.7098

The AUC values of the plasma and tissue concentration-time profiles were calculated for Compound 17 and Compound 7 and shown in Table 9.

TABLE 9

T3 Mimetic	Plasma AUC	Liver AUC	Heart AUC	Kidney AUC
Compound 17	2.8 µg·hr/mL	48.5 nmol·hr/g	27.6 nmol·hr/g	1.1 nmol·hr/g
Compound 7	31.6 µg·hr/mL	301.7 nmol·hr/g	32.8 nmol·hr/g	5.0 nmol·hr/g

Conclusion: Compared to the phosphonic acid T3 mimetic (Compound 7), the carboxylic acid T3 mimetic (Compound 17) had significantly higher plasma clearance and volume of distribution in the rat. Substantially higher levels of Compound 7 measured in the liver indicated good penetration of the T3 mimetic phosphonate into the

target organ. Compound 7 showed higher liver exposure relative to Compound 17. Thus, phosphonic acid T3 mimetics have greater liver specificity, as compared to heart tissue, than do carboxylic acid T3 mimetics.

Example I: Subacute Studies in Cholesterol fed Rats Cholesterol Reduction

The purpose of these studies was to evaluate the effects of a carboxylic acid T3 mimetic (Compound 18) a phosphonic acid T3 mimetic prodrug (Compound 13-1-cis) on serum cholesterol and TSH levels, hepatic and cardiac gene expression and enzyme activities, heart weight, and clinical chemistry parameters.

Methods: Rats were maintained on a diet containing 1.5% cholesterol and 0.5% cholic acid for 2 weeks prior to initiation of treatment. Serum cholesterol values were assessed and the animals randomized into groups for treatment. Serum cholesterol was analyzed using a commercially available enzymatic kit (Sigma Diagnostics, St. Louis, MO). Compound 13-1-*cis* and Compound 18 were administered PO once a day for seven days. Serum TSH is measured using an enzymeimmunoassay (EIA) kit designed for rat TSH (Amersham Pharmacia Biotech, Arlington Heights, IL). Expression levels of liver genes (*e.g.*, the LDL-receptor, apoB, cpt-1, spot14 and apoAI) and heart genes (*e.g.*, Serca2, HCN2,Kv1.5, MHCα, MHCβ, Alpha1c) are quantified by Northern blot analysis or by RT-PCR. For Northern analyses, RNA is isolated from liver tissue by a guanidinium thiocyanate method, and total RNA is obtained using an RNeasy column (Quiagen). mRNA is separated on a 1% agarose gel and transferred to a nylon membrane. Oligonucleotides specific for the complementary gene sequences are used to make ^{32}P-labeled probes (Multiprime DNA labeling systems, Amersham Pharmacia Biotech). Following hybridization of the probes to the nylon membranes, radioactivity is assessed on a blue film (Eastman Kodak Co,), and the resulting image quantified using the appropriate software. RT-PCR is performed using an iCycler instrument (Biorad) using appropriate primers by means of standard methodology [*e.g.*, Schwab DA *et al.* (2000) *Life Sciences* 66: 1683-94]. GPDH activity in liver and heart are measured as described in Example B. The activities of PEPCK and glucose 6-phosphatase in liver are measured by means of direct enzymatic assays of homogenized liver tissue as described by Andrikopoulos S *et al.* (1993) *Diabetes* 42: 1731-1736. Alternatively, expression levels of the corresponding genes are determined by Northern blot analysis or RT-PCR as described above.

Results: Doses of 0.6-50 mg/kg/day of Compound 13-1-*cis* significantly decreased serum cholesterol (*see* Figure 5). Compound 18 at 1 mg/kg/day significantly decreased serum cholesterol. No significant undesirable cardiac hypertrophy was observed with Compound 13-1-*cis* at any dose tested.

Conclusion: Compound 13-1 showed significant cholesterol lowering even at the lowest dose evaluated (0.6 mg/kg). Furthermore, no evidence of undesirable effects on heart weight was observed across the entire dose range tested (up to 50 mg/kg).

Example J: Decreases In Hepatic Fat Content Following Treatment With A Phosphonic Acid Thyromimetic:

Normal rats were chronically infused with Compound 7 for 7 days. Liver triglycerides were analyzed following lipid extraction by the Bligh Dyer method (Bligh EG and Dyer WJ, A rapid method of total lipid extraction and purification. Can J Med Sci. 1959 (August); 37(8):911-7, incorporated herein by reference). Total triglycerides were analyzed in the liver extracts by an enzymatic assay (Thermo Electron Corporation). Total lipid was normalized to initial liver weight and triglyceride content was normalized to liver weight. T3 administration would not be expected to decrease liver triglyceride content. Analysis of hepatic triglyceride content in the T3 infused rats showed no significant decrease in triglyceride content. There was a 4% reduction in liver triglycerides for this group and the results were not statistically significant. The Compound 7 infused animals demonstrated a decrease in hepatic triglyceride content of 64%, an unexpected and significantly different result.

In other experiments, Compound 7 was orally administered to ZDF rats for 28 days. Liver triglycerides were analyzed as described above. Total liver triglycerides were reduced in the treated animals 42% in the 2.5 mg/kg/d group. Histologic analysis of liver sections following H&E staining demonstrated a pronounced and diffuse microvesicular steatosis throughout the hepatic lobule in the vehicle treated group. The hepatic steatosis is a well known and described phenomenon for the ZDF rat, and therefore not attributable to vehicle treatment. There was a dose dependent reduction in the microvesicular steatosis and a noticeable appearance of intact cytoplasm within the hepatocytes consistent with a non-steatotic liver.

Example K: Effects of Phosphonic Acid T3 Mimetic Prodrugs *In Vivo* on Cholesterol

Another experimental assay was to evaluate the effects of prodrugs of phosphonic acid T3 mimetics of the present invention on serum cholesterol. Rats were made hypercholesterolemic by maintainence on a diet containing 1.5% cholesterol and 0.5% cholic acid for at least 2 weeks prior to initiation of treatment. Plasma cholesterol values were assessed prior to and following treatment and the effects of compound were expressed as a percentage change from the pre-dose cholesterol levels. Total cholesterol was analyzed using a commercially available enzymatic kit (Sigma Diagnostics, St. Louis, MO). Compounds were routinely tested for oral efficacy at a dose of 0.5 mg/kg/d. Hypercholesterolemic rats were treated with vehicle, Compound 13-1-cis (a HepDirect version of Compound 7), Compound 19-1 (a diethyl ester of Compound 19-2), Compound 13- 9 (a HepDirect version of Compound 19-2), Compound 12-5 (a bisPom version of compound 19-2), or Compound 15-5 (a bisamidate version of Compound 19-2) at 0.5 mg/kg/d orally. Compound 13-1-*cis* has been extensively characterized and was used as the positive control for the assay. Vehicle, Compound 13-9 and Compound 19-1 failed to demonstrate cholesterol lowering in this assay while Compound 13-1-*cis*, Compound 12-5 and Compound 15-5 demonstrated a significant lowering of cholesterol. HepDirect versions of the phosphonic acid T3 mimetics normally show good results, however, diethyl ester versions of the phosphonic acid T3 mimetics of the present invention were found not to be suitable as prodrugs.

In another experiment, the efficacy of Compound 7 was compared to Compounds 12-9, *cis*-13-2 and 15-6, which are prodrugs of a compound that binds poorly to both TRα and TRβ (Ki of about 300nM). Compound 7 was efficacous whereas Compounds 12-9, cis-13-2 and 15-6 were not efficiacous in lowering cholesterol.

Table 10 (below) shows the results for additional compound of the present invention assayed in the present method.

TABLE 10

Compond delivered i.p (0.2 mg/kg/d)	% Cholesterol Lowering
Untreated	-3.6
Vehicle	-5.3
40	-64.2
7-5	-63.3
7-9	-63.2
24-3	-48.6
8-2	-48
45	-46.3
7-3	-45.4
22	-44
66	-42.9
7	-41.5
11	-36.4
24-1	-35.4
7-14	-32.9
33	-32.5
46	-29.6
47	-29.3
42	-28.8
7-8	-28.6
7-10	-25.8
8	-24.3
48	-23.4
29	-21.9
38	-21.7
31	-21.1
27	-20.8
24-2	-20.5
28	-20.5
6	-20.5
19	-19

52	-18.8
7-6	-13.5
37	-0.4

Compound Delivered p.o. (0.5 mg/kg/d)	% Cholesterol Lowering
Untreated	-3.96093
Vehicle	-5.07855
15-4	-39.5579
12-8	-33.7214
12-5	-32.5195
cis-13-1	-31.7885
12-4	-30.4743
15-5	-29.8974
15-7	-29.1462
13-8	-26.4936
13-11	-24.7878
13-9	-10.9392
19-1	-6.5639
12-7	-39.1
13-10	-25.8
15-8	-31.1

Example L: Effects of Phosphonic Acid T3 Mimetic Prodrugs *In Vivo* on Circulating TSH

Another concern with synthetic thyromimetics is the suppression of the endogenous thyroid axis. Thyroid homeostasis is maintained by the action of thyroid releasing hormone (TRH) and thyroid stimulating hormone (TSH). TRH is produced in the paraventricular region of the hypothalamus (Dupre, SM et al, Endocrinology 145:2337-2345 (2004). TRH acts on the pituitary releasing TSH which then acts on the thyroid organ itself. The levels of TRH and TSH are controlled by a feed-back sensing mechanism so that low levels of thyroid hormone (TH) (T3 or T4) will cause an increase in TRH and TSH and elevated levels of TH will cause a suppression of TRH and TSH. Because TSH can be measured more readily than TRH, levels of TSH are tested as a measure of systemic effects of TH or synthetic thyromimetics. Decreased TSH levels are a concern because suppression of the thyroid axis could lead to systemic hypothyroidism.

Although this particular side effect has been noted, it has typically been treated with less concern than the cardiac safety issues. However, new evidence indicates that, in addition to possible systemic hypothyroidism, which is a concern for any potential long-term therapy, TSH suppression will enhance osteoclast function leading to a decrease in bone mass and loss of bone structural integrity (Abe, E et al, Cell 115:151-62 (2003)). Therefore previous investigators have measured TSH levels when testing synthetic thyromimetics and have used a 30% decrease of TSH as the denominator in their therapeutic index calculations. The therapeutic index of TSH levels in cholesterol-fed rats, treated with either Compound 17 or Compound 18 (both carboxylic acid T3 mimetics) for 7 days, are 0.8 and 0.4, respectively. Therefore, both compounds suppress TSH as doses lower than that required to decrease circulating cholesterol. In ZDF rats treated with 50 mg/kg/d Compound 7 for 28 days, no statistically significant difference from vehicle was measured for TSH. However, 0.2 mg/kg/d of Compound 18 in 28 day treated ZDF rats, decreased TSH levels greater than 90%. In mice treated with 10 mg/kg/d Compound 7 for 77 days, no decrease in TSH was observed, indicating that Compound 7 can significantly decrease cholesterol levels without producing an adverse effect on the endogenous thyroid axis.

Example M: Effects of Phosphonic Acid T3 Mimetic Prodrugs In Vivo on Glucose

Plasma glucose in Comound 7 treated ZDF rats at sacrifice decreased from 618 mg/dL to 437 mg/dL following 4 weeks of treatment with Compound *cis*-13-1. The decrease was dose dependent. Blood glucose levels at those doses corresponded to 442 mg/dL and 243 mg/dL, respectively. Similar changes were also evident at two weeks, post-treatment. There was a dose-dependent decrease in the water consumption of the treated animals, which is consistent with an improvement in glycemic control.

Example N: T3 and T3 mimetic mediated myosin heavy chain gene transcription in the heart

An RT-PCR assay as disclosed in: Sara Danzi, Kaie Ojamaa, and Irwin Klein *Am J Physiol Heart Circ Physiol* 284: H2255-H2262, 2003 (incorporated herein by reference) is used to study both the time course and the mechanism for the triiodothyronine (T3)-induced transcription of the α- and β-myosin heavy chain (MHC) genes in vivo on the basis of the quantity of specific heterogeneous nuclear RNA (hnRNA). The temporal relationship of changes in transcriptional activity to the amount

of α -MHC mRNA and the coordinated regulation of transcription of more than one gene in response to T3 and T3 mimetics are demonstrated. Analysis of a time course of T3 and T3 mimetics that are not liver specific show mediated induction of α -MHC hnRNA and repression of β-MHC hnRNA, whereas no significant affect is observed with compounds of the present invention at doses that are therapeutically useful.

Example O: Cardiovascular activity of T3 Mimetics in the Rat

The objective of these experiments was to evaluate the effect of phosphonic acid containing T3 mimetics versus carboxylic acid containing T3 mimetics, on cardiovascular function (heart rate, inotropic state, and aortic pressure) in the Sprague Dawley (SD) rat model.

Method: Compound *cis*-13-1 (a HepDirect prodrug of Compound 7) was dissolved in PEG400 and administered daily to SD male rats (n=6/group) by oral gavage (1, 5, 10, 30, 50 mg/kg/day) at 1 ml/kg body weight. The control group (n=6) was given vehicle only. Compound 18 (a carboxylic acid T3 mimetic) was administered at 1 mg/kg p.o. as a positive control (n=6). On the 7th day after the start of dosing, animals were anesthetized with Isoflurane and the left ventricle cannulated with a high fidelity catheter tip transducer via the right carotid artery. Left ventricular pressure, its first derivative (LVdP/dt), lead I ECG, and heart rate (HR) triggered off the ECG waveform, were digitally recorded. LV dP/dt is a well accepted measure of ionotropic state. Systolic and diastolic aortic pressures were measured by retracting the catheter into the proximal aorta.

Results: Compared to vehicle treated animals, Compound 18 administration resulted in marked and statistically significant increases in HR, LV dP/dt, and systolic aortic pressure after 7 days of treatment. In contrast, HR, LV dP/dt, systolic and diastolic aortic pressures in all groups treated with Compound *cis*-13-1 were not significantly different compared to vehicle treated animals. Heart weight and heart weight normalized to body weight in Compound 18 treated animals were significantly increased compared to control animals. There were no significant changes in heart weight or heart weight/body weight ratios in Compound cis-13-1 treated groups.

Conclusions: It is concluded that Compound *cis*-13-1 when administered at doses up to 50 mg/kg/day for 7 days is devoid of significant chronotropic and inotropic effects in the normal SD rat. This stands in contrast to Compound 18 which is associated with marked effects when given at 1 mg/kg/day.